TEACHERS ACROSS BORDERS

PHYSICAL SCIENCE

Grades 10 - 12

Bloemfontein: July 17 - 21, 2017

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Feel The Force: Understanding Electrostatics

Materials Needed:

- Empty Aluminium Can
- Latex Balloon
- Styrofoam Cup, or Styrofoam Plate/Tray
- Bits of paper
- Plastic drinking straws (Flexi if available)
- A roll of 3/4 inch (1.5 cm) wide Scotch Magic Tape™ (Transparent Tape, not cello tape)
- A plastic comb

Procedure:

1) Start by blowing up the balloon.

2) Place the can on its side on a flat smooth surface like a table or a smooth floor.

3) Rub the blown up balloon back and forth through your hair really fast. What happens to the balloon? What happens to your hair? You can use an old wool sock or a plastic bag too.

4) Have the students predict what will happen if they hold the balloon close to the can without actually touching the can. (Have them write this prediction down). Once students have made their predictions have them try it. Have the students record their observations.

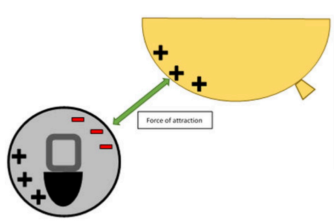
2 

3 

4 

Scientific Explanation: (in detail)

When you rub the balloon through your hair invisible electrons (with a negative charge) are stripped off the atoms that make up your hair and build up on the surface of the balloon. This is building up of charge is called static electricity, which means “non-moving electricity”. The electrons have given the balloon a negative charge relative to the can and it now has the ability to attract objects (neutral or with a positive charge) toward them – like the soda can.



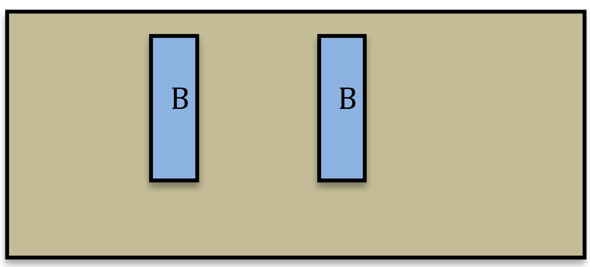
Understanding Static Electricity:

How can you measure the charge of an object using simple items like straws, Styrofoam cups, Styrofoam plates, Magic Tape™, aluminium cans, balloons, and your hair?

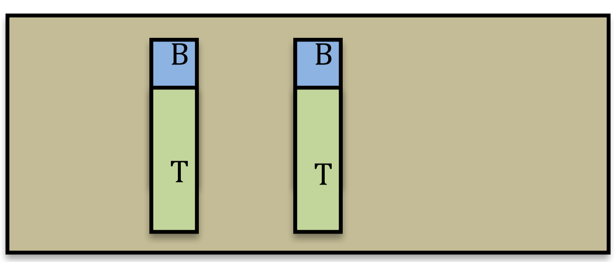
Getting Started:

1. Pull off two 10 cm (4") lengths of tape. Be sure to fold over a small part (about 2 cm) at one end so you can pick the tape up easily. Now stick the tape on your desk and smooth them down. Call these your OLD tapes. Mark with an "O".
2. Pull these OLD tape lengths off the table and hang them from the edge of a table to age.

3. Pull off two more 10 cm lengths of tape and stick them down on the table, these are your BASE tapes. Be sure to fold the end of the tapes back on themselves to make a handle. Call these your BASE tapes and mark with a "B".



4. Pull off two more 10 cm lengths of tape and stick them down on top of the two BASE tapes. Fold the end of the tapes back on themselves to make a handle. Call these your TOP tapes and mark these with a "T". **(Predict what will happen if you pull these off and hold close to each other. Please record your prediction.)**



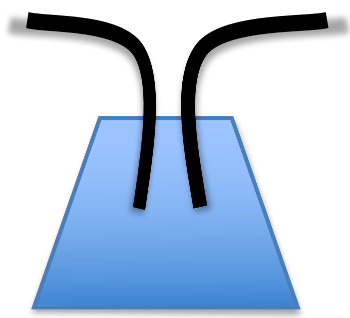
5. Quickly pull off the two top tapes and hold one in each hand so that each hangs down vertically. (If one sticks to your hand shake it free.) Bring the two tapes near each other and observe what happens. **(Please record your observation.)**
6. Place the TOP tapes back on the BASE tapes and smooth them out again. Then pull up one set of TOP and BOTTOM tapes. Keep them together. Stroke them gently between your fingers a few times until they no longer attract your hand.

7. Pull the tapes apart rapidly and hold one in each hand. Bring them together. Observe what happens. **(Please record your observation. What do you think this behavior indicates?)**
8. Now revisit the two OLD tapes. Hold one of the OLD tapes in each hand so that they hang down vertically. Bring them together. **(Pease record your observation. Why do you think the OLD tape shows this behavior?)**
9. Place the OLD tapes back on the edge of the table. Recharge a BASE and TOP tape system like you did in step 6. **(Predict what will happen when you bring the TOP or BASE tape close to the OLD tape. Please record your prediction.)** Once you have these tapes charged bring the TOP tape close to the OLD tape. **(Please record your observation. What do you think this behavior indicates?)** Please repeat this step using the BASE tape and the OLD tape. **(Do you observe the same reaction?)**
10. Find a partner and test the following pairs of tapes: two TOP tapes, two BASE tapes, TOP and BASE tapes. **(Please record your observation. What do you think these behaviors indicate?)**

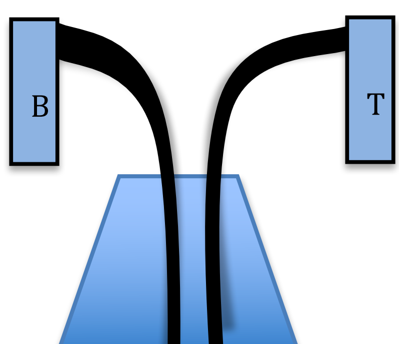
Building an Electroscope:

1. Put two straw size holes in the "bottom" of your Styrofoam cup and then turn over the cup so that the hole is now at the top.

2. Place the long portion of a flexi-straw into the hole with the short portion bent 90 degrees to the cup.



3. Recharge a BASE and TOP tape system like you did in the previous activity and place the TOP tape on one of the straws and the BASE tape on the other straw.



4. From our previous experiment we know that one of these is positive the other is negative. Now rub a Styrofoam plate with your hair if it is clean and free of oils or additives, otherwise rub the plate with wool. Bring the plate close to (but not touching) each of the tapes on the electroscope. **(Please record your observation.**

What do you think these behaviors indicate?)

5. Ben Franklin was one of the first people to systematically study the effects of materials that are rubbed together. He noticed that for some reason each became charged, Ben Franklin did not know which one gained charge and which one lost charge. He proposed an arbitrary standard. He said, if you rub amber (solidified tree sap) with cat fur, then, by definition, the amber becomes minus, while the fur becomes plus. We still use his proposed standard today. Rub a Styrofoam cup or plate with a piece of wool or clean dry hair and by Ben Franklin's definition the cup or plate becomes negatively charged and the wool or hair becomes positive. This definition can be used to determine the charges on objects. Based on this definition what charge can you give the TOP tape? The BASE tape?

Going Further:

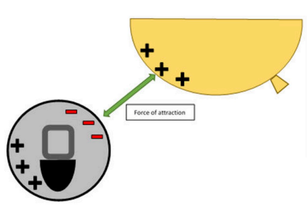
1. Rub the Styrofoam Cup on your hair. Does this have the same effect on the can?
2. Rub a Drinking Straw on your hair. Does this have the same effect on the can?
3. Which of the objects had more "Power to Pull"? Why do you think this is so?
4. How do you think this relationship would be impacted by the size of the balloon?
5. Does the length of the persons' hair effect the power of the static electricity?
6. Just how strong is the static charge anyway?
7. Is the electrical force greater or smaller than the gravitational force?

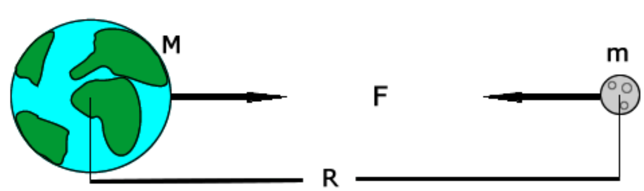
How Strong is this force?
The Electrostatic Force, one type of Non-Contact Force is actually very strong and we can calculate it with a simple equation:

$$F = k\frac{q_1 q_2}{r^2}$$

The symbol k is Coulomb's law constant (9×10^9 N. m^2/C^2), Q_1 and Q_2 represent the quantity of charge on object 1 and object 2, and r represents the separation distance between the objects' centers.

For the sake of ease in this problem we are not going to fret about the actual charge in Coulombs of the two objects since the charge, Q of one electron or one proton is very close to the miniscule amount of 1.60×10^{-19} Coulombs. We will simply state that the balloon, charge Q1, has a value of 10C and the Can, charge Q2, has a value of -10C and the distance between the two objects was .10 m. Give this information, what is the force between the Can and the Balloon?





How does this force compare with Gravitational Force?
Is it "stronger" or weaker"? Given the equation for Gravitational Force:

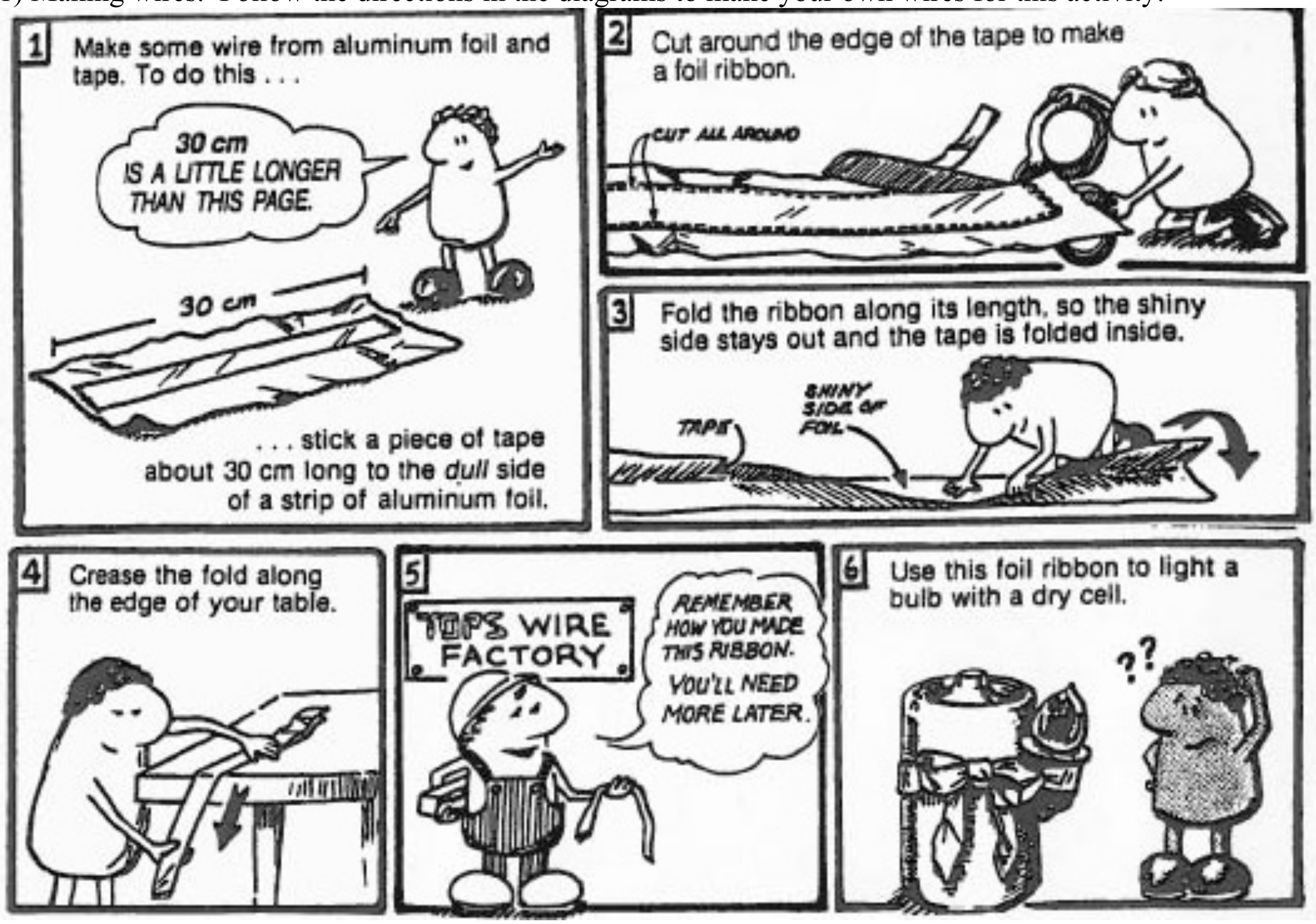
$$F_g = G\frac{m_1 m_2}{r^2}$$

Where the symbol G is the Gravitational Constant (6.673×10^{-11} N m^2/kg^2), and m1 and m2 represent the masses of object 1 and 2, and r represents the separation between the objects' centers. Electrostatic Force is much stronger than gravity…over short distances.

It Shocking: Exploring Electrical Circuits

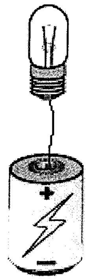
Materials Needed:
- Batteries
- Bulbs
- Wires (made using aluminium foil)

Procedure:
1) Making wires. Follow the directions in the diagrams to make your own wires for this activity:



2) On the next page are diagrams of 10 different configurations of bulbs, wires, and batteries. **Before trying any of the configurations with the materials provided, make a prediction (light or not light) about whether or not each configuration will result in the bulb lighting up.** Make your prediction by yourself and note your prediction in the space provided on your lab sheet. When all the members of your lab group have finished with your predictions, compare your predictions for each configuration with those of your lab partners and indicate by a number what each of you believe will happen.

3) Now, with the equipment provided, try each of the 10 configurations shown illustrated below. Use the pieces of bare wire, and hold them in contact with the battery and bulb as the figures show. (Caution: If you Short Circuit the Battery, the wires will get **HOT**.) In each case note if the light bulb comes on in the **Obs:** area provided. Overall how did your team do in its predictions? In other words how many of you were right for each of the predictions?



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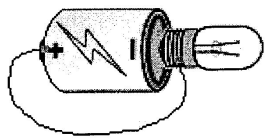

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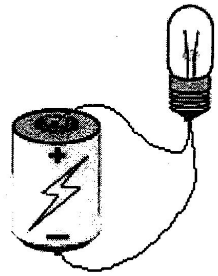

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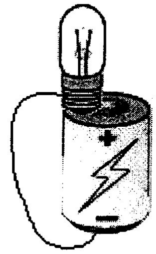

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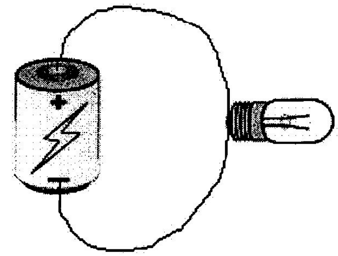

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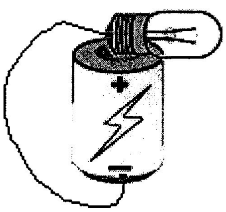

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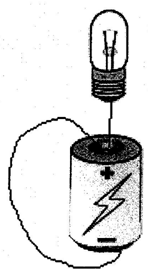

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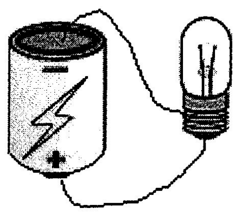

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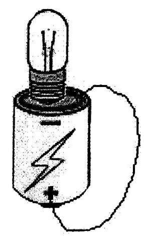

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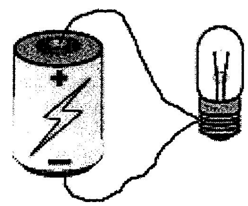


#10

Pred: Obs: Pred: Obs: Pred: Obs: Pred: Obs: Pred: Obs:

Going Further:

1. Now that you are an expert, what is necessary for the bulb to light?

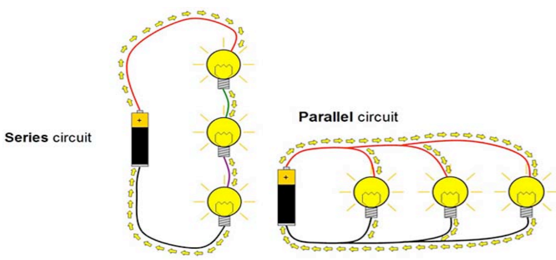
2. How many of the configurations met this need?

3. How did your predictions and your observation align?

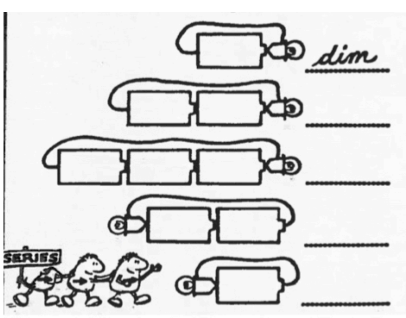
Scientific Explanation: (in detail)

An electric circuit is like a pathway made of conductors where electrons push on the electrons in front of it, which pushes on the one in front of it, and so on, and so on, just like a hula-hoop filled with marbles. Now, all we need to maintain this flow is a continuous means of motivation for those electrons, a battery or other power source gives the motivation or force (voltage) that makes the electrons move. When the electrons get to a device (load) a light bulb, your TV, or a refrigerator, they give it the power to make it work. After your experience with the battery, wire and bulb, it must be realized that continuity is important in a circuit. Any break in this continuity will prevent electrons from flowing through it.

Parallel and Series Circuits:

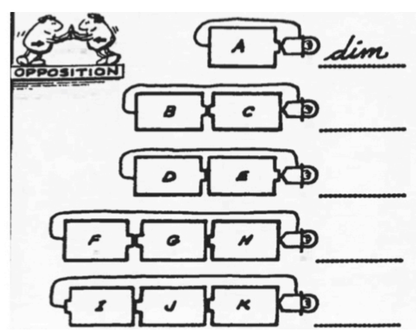


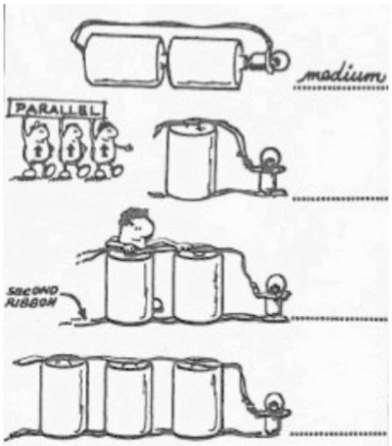
A series circuit is a closed circuit in which the current follows one path, as opposed to a parallel circuit where the circuit is divided into two or more paths. In a series circuit, the current through each load is the same and the total voltage across the circuit is the sum of the voltages across each load.



If the bulb shines “dim” with 1 cell, find out how it shines with more cells connected in series. Record if it shines bright, medium or dim.

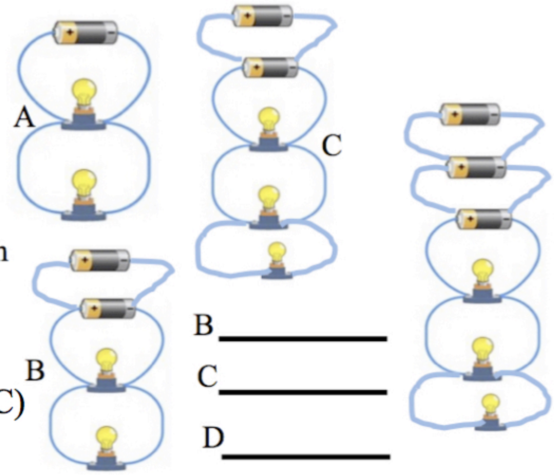
If the bulb shines “dim” with 1 cell, find out how it shines with more cells connected in series. Record if it shines bright, medium, dim or not at all.





If the bulb shines medium with 2 cells in series, find out how it shines with cells connected in parallel: bright, medium or dim.

If the bulbs shine dim with 1 cell in parallel (A), find out how it shines with 2 cells connected in parallel (B) and then determine: bright, medium or dim for configuration (C) and (D).



B ____________

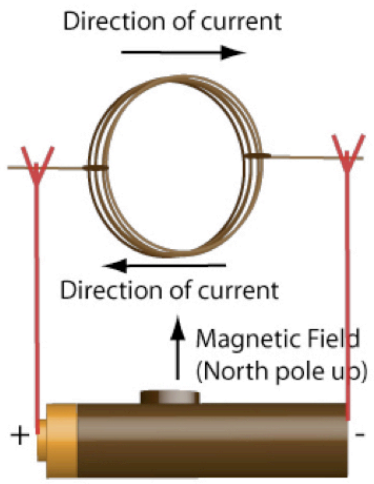
C ____________

D ____________

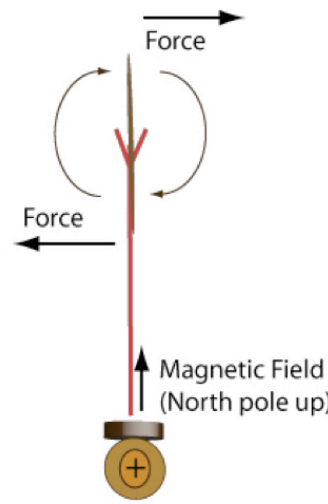
Electricity and Magnetism: Working Together to Power the World
Building a Simple Motor to demonstrate the relationship between electrical current and magnetism.

Simple Motor:

1. Starting in the center of the wire, wrap the wire tightly & neatly around the battery several times.
2. Slide the coil you made off the battery.
3. Wrap each loose end of the wire around the coil a few times to hold it together, then point the wires away from the loop. Use sandpaper to remove the top-half of the wire insulation on each free end of the coil. The exposed wire should be facing the same direction on both sides.
4. Thread each loose end of the wire coil through a bent open paper clip. Try to keep the coil as straight as possible without bending the wire ends.



** the coil is wound clockwise



5. Lay the battery sideways on a flat surface.
6. Tape the battery down so it does not roll away.
7. Place the paper clips upright next to the terminals of each battery so that the side of each needle touches one terminal of the battery & tape them in place.
8. Tape the small magnet to the side of the battery so that it is centered underneath the coil.
9. Give your coil a spin. *What happens? What happens when you spin the coil in the other direction? What would happen with a bigger magnet? A bigger battery? Thicker wire?*

Scientific Explanation: (in detail)
The metal, paper clips, and wire create a closed loop circuit that carries current. Current flows from the negative battery terminal, through the circuit, and to the positive battery terminal. Current also induces a magnetic field in the coil, which helps explain why the coil spins. Magnets have two poles, north and south. North-south interactions attract, and north-north and south-south interactions repel. The magnetic field created by the current in the wire is not perpendicular to the magnet taped to the battery, so a least some part of the wire's magnetic field will repel and cause the coil to continue to spin.

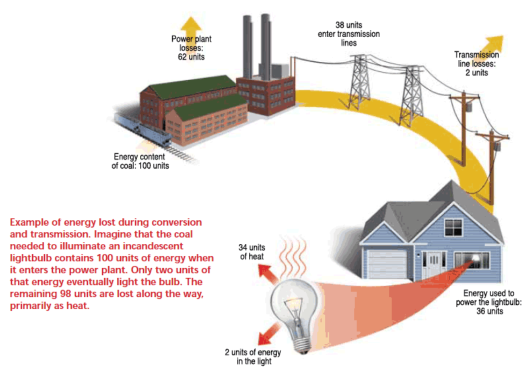
Energy and Electrical Costs in South Africa:

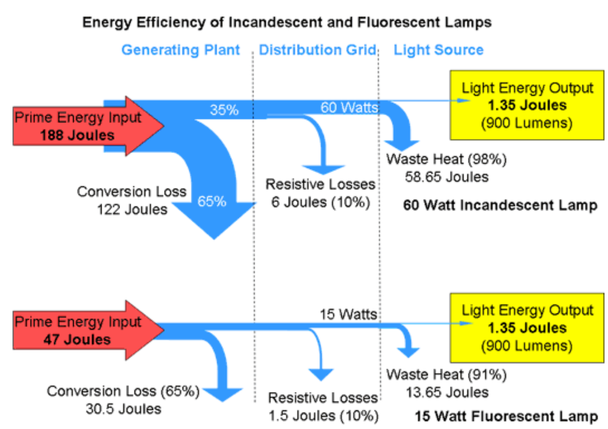
V = voltage measured in volts   I = Current measured in Amps   Energy = kWh or Joules
R = Resistance measured in Ohms Ω   P = Power measured in watts   South African Voltage = 230 V

Eskom average per unit price of electricity is 105,66 c/kWh for 2017 – 2018

4 watt Cell Phone Charger	60 watt Light Bulb	1500 watt Toaster	400 watt Television
I = ____________ A	I = ____________ A	I = ____________ A	I = ____________ A
V = ___________ V	V = ___________ V	V = ___________ V	V = ___________ V
R = ___________ Ω	R = ___________ Ω	R = ___________ Ω	R = ___________ Ω
P = ___________ w	P = ___________ W	P = ___________ W	P = ___________ W
= ___________ Kw	= ___________ Kw	= ___________ Kw	= ___________ Kw
Cost to charge for 8 hrs.	Cost to light for 24 hrs.	Cost to toast 6 slices of bread (5 minutes each)	Cost to watch for 5 hrs.
_________________	_________________	_________________	_________________

True Cost of Energy:





The preceding example shows the inefficiencies involved in converting a primary energy supply into useful light output. A typical 60 Watt incandescent lamp produces illumination of about 15 lumens per Watt of applied power. The total light output from the bulb is therefore 900 lumens, which is equivalent to about 1.35 Watts or 1.35 Joules per second of radiated light power, and the conversion efficiency is 2.25%. The rest of the applied electrical energy is lost as heat. The typical efficiency of an electricity generating plant is 35% and a 10% Joule heating losses in the distribution grid, the efficiency of converting primary energy into light energy is only 0.7%

For comparison, a compact fluorescent lamp (CFL) produces between 50 and 60 lumens per Watt. By using fluorescent rather than incandescent lamps, the power consumption of the lamps can be reduced from 60 Watts to 15 Watts for the same light output. The consumer saves a modest 45 Joules per second but the corresponding prime energy consumption is reduced by a massive 141 Joules per second.

How much electricity does appliances use?

Coffee machine: 900 – 1200 Watts
Washing machine: 350 – 500 Watts
Tumble-dryer: 1800 – 5000 Watts
Electric blanket: 60 – 100 Watts
Hair dryer: 1200 – 1875 Watts
Portable heater: 750 – 1500 Watts

Iron (clothing): 1000 – 1800 Watts
Computer: 30 – 150 Watts
Laptop: 50 – 75 Watts
Microwave: 750 – 1100 Watts
Bread Toaster: 1100 Watts
Refrigerator: Between 500 – 1400 Watts

The Basic Rocket Car, Newton's Laws and the Work – Energy - Theorem

Rocket cars are great for kids to build, and they make a fun project to help students understand Newton's Laws, especially the Third Law of Motion, which states that every action has an equal and opposite reaction.

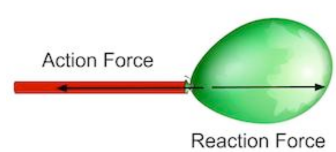
Materials Needed:

- Ruler
- Scissors
- Nail
- Pen
- Empty Plastic Soda or Water Bottle
- 1 Latex Balloon
- 4 Plastics Soda Bottle Caps
- 3 Plastic drinking straws (Flexi if available)
- A roll of 3/4 inch (1.5 cm) wide tape)
- 2 Bamboo Skewers

Procedure:

1. Carefully pierce the middle of the Empty Plastic Bottle with a hole large enough for a drinking straw.
2. Place the straw into the bottle with the shorter end out the hole you pierced into the bottle.
3. Find the center of the wheels as best you can and mark with a pen. This will be the point where the axle will go through the wheel. Then carefully pierce the middle of the Plastic Bottle Caps to use as wheels.
4. Carefully cut the two remaining straws so that you remove the short end and the flexi section. These will be used as bushings for the axles.
5. Cut the bamboo skewers to a length about 2 centimeters longer than the width of your cut straws.
6. Tape these straw pieces on to the bottom of the car body as close to parallel as possible and separated by a distance that you feel "looks good" for your car.
7. Carefully press one of the wheels on to each of the skewers and then slide the skewers through the straw bushings. Carefully press the other wheel on each axle.
8. Tape the balloon onto the straw sticking through the hole you made in the Plastic Bottle.
9. Carefully blow-up the balloon using the straw and then once filled, pinch off the straw until ready to race.
10. When you are ready to race, simply release your fingers from the straw. If your car doesn't roll or it curves when powered by the balloon adjust until you get a good straight run.
11. Race with another group. How far did your car go? How fast did it go? How does this show the 1st Law of Motion? The 3rd Law of Motion?

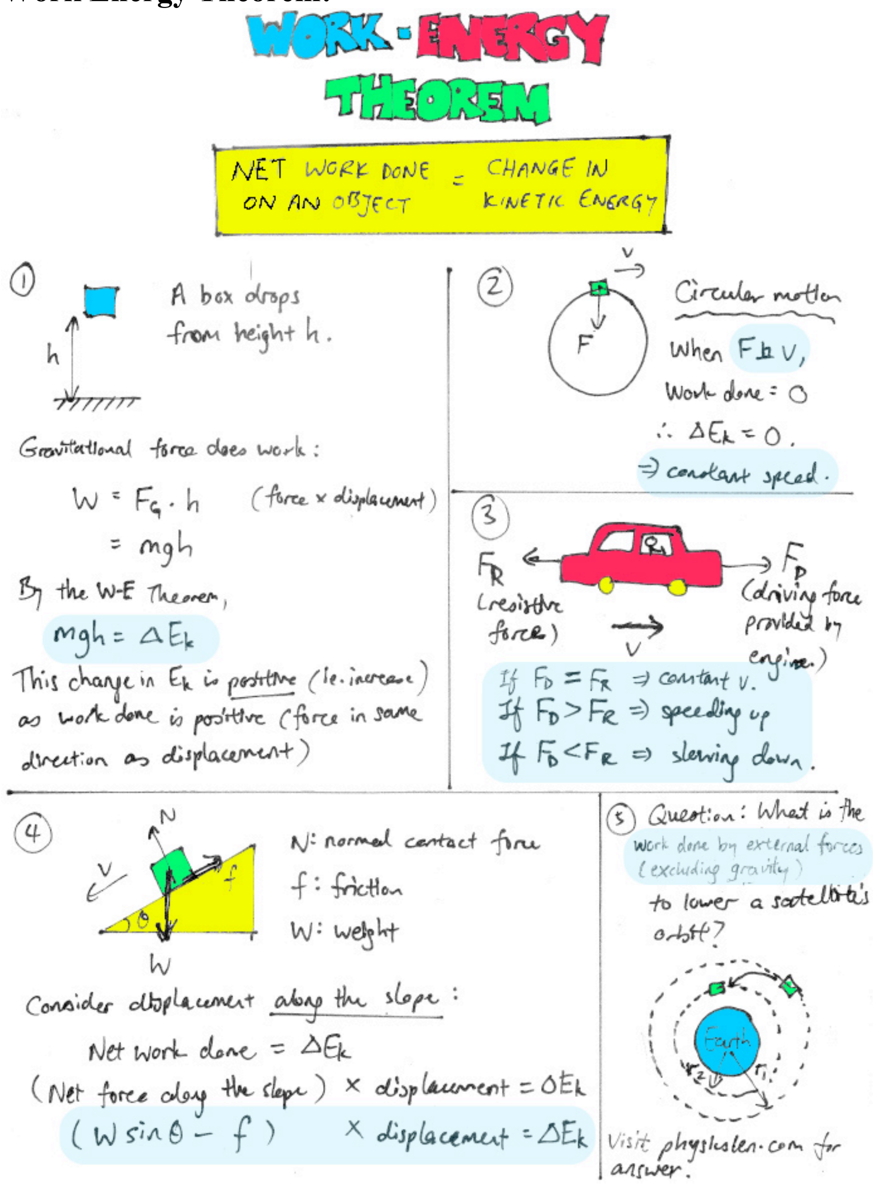


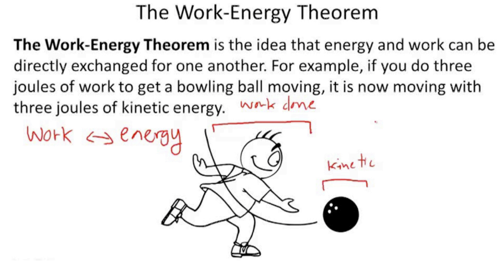



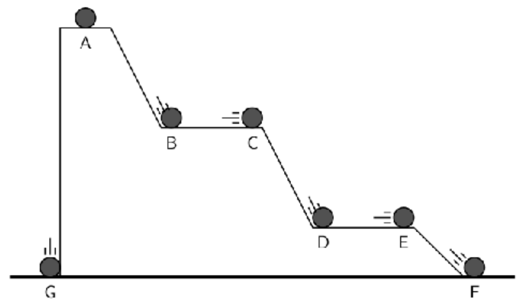
Scientific Explanation: (in detail)
Before you release your pinch on the inflated balloon, the car is at rest. Once you let it go, escaping air from the balloon rushes out of the straw. This is your car's propulsion system. The principle at work is Newton's Third Law of Motion. This law states that for every action, there is an equal but opposite reaction. In the case of the Balloon-Powered Car, the action is the air rushing from the straw and pushing against the air behind the car. The reaction is the air behind the car pushing against the car with the same force causing the forward movement of the car.

The potential energy of the car is stored in the expanding elastic material of the balloon. As the balloon fills with air, it adds more potential or stored energy. As the air flows from the balloon, the energy changes to kinetic energy or the energy of motion. The moving Balloon-Powered Car is using kinetic energy. If you design your car very well, it will continue to roll for a bit after all the air is expended from the balloon because an object in motion tends to stay in motion.

Work Energy Theorem:





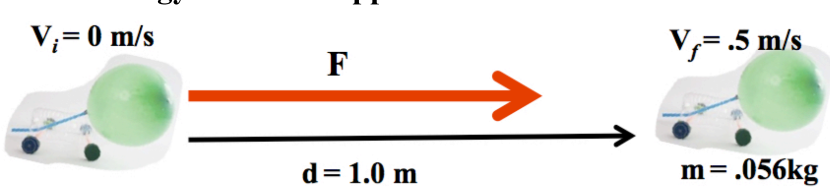


Fill in the table with the missing information using the positions of the 2-kg ball in the diagram above combined with the work-energy theorem. Remember that in this situation total Energy is conserved. Round g to 10m/s^2. For v consider fast, medium, slow, none.

Position	KE	PE	V
A		100J	
B		50J	
C			
D		20J	
E			
F			
G			

Does Newton's 2nd Law relate to your Rocket Car?

Work Energy Theorem Applied To Your Rocket Car:



$\Delta KE_{car} = ½mv_f^2 – ½mv_i^2$

$\Delta KE_{car} = \{½(.056)0.5^2 – 0\}\ kg\ m^2/s^2 = .007J$

Work Energy Theorem W=ΔKE

Work W=Fd

$Fd = \Delta KE = ½mv_f^2 – ½mv_i^2$
$F(1.0m) = ½(.056)0.5^2 = .007J$

F =.007J/1.0m = .007J/m = .007N
force of air on car!

The Gravity of the Situation

Materials Needed:

- Two metal forks or a metal fork and a metal spoon
- wooden toothpicks or wood matches
- Glass or jar (don't use plastic)

Procedure: (include illustrations if possible)

1) Start by pushing the two center tines on the fork upward a little. (This is probably not the best thing to do with heavy or expensive utensils; cheaper is probably better.)

2) Push the fork and spoon together so the bowl of the spoon is *under* the two center tines, but *over* the outer two tines of the fork. It's useful if the fork and the spoon weigh about the same.

3) This step may take some practice. Balance the utensils on a fingertip to find the middle point. This is where the toothpick should be inserted between the utensils. Work the toothpick into the tines of the fork. Then carefully set the toothpick on the rim of the glass. Slowly slide it in or out across the rim until you've found the best "balance point". Both handles will be curving downward below the rim of the glass and the toothpick will be almost horizontal.

1  2  3 

4) Once you've mastered the balance, you're ready to burn the toothpick of wood match. Have students predict what they think will happen to the balanced utensils when the toothpick or match burns. (Have them write this prediction down).

4 

5) Once students have made their predictions, strike a match (that's a job for an adult) and burn the end of the toothpick hanging over the **inside** of the glass. Have the students record their observation. When that flame stops, light the end on the **outside** of the glass and watch it burn. Have them write down their observation of the whole system. Ask

them why the toothpick or match burned out? Ask them where the center of gravity is for this system.

Scientific Explanation: (in detail)

The toothpick will burn down to the very edge of the glass but the utensils will not fall. Why is this? Why didn't the flame keep burning and cause a collapse? Fire requires three things: heat, fuel, and oxygen. Take away one of these and the fire goes out. In this case the fuel (wood) and oxygen (air) are still present but metal and the glass remove the heat from the system faster than the wood, robbing the flame of its heat and it dies. This is due to the specific heats of these objects. Glass = 840 J/kg^{o}C, Stainless Steel = 502 J/kg^{o}C, Birch Wood = 1900 J/kg^{o}C

Why did the utensils remained balanced? The center of gravity of an object refers to the central location that gravity acts on the object. In this activity, the center of gravity is straight down from the spot where the toothpick or wood match sits on the rim of the glass (called the pivot point). If you look closely at your balancing utensils, you'll notice that the handles are curved well below the toothpick. This actually moves the center of gravity directly *below* the point where the toothpick touches the rim.

If the glass has slanted sides, the center of gravity— where the utensils balance front and back, left and right, up and down— may actually be located in mid-air next to the glass. A tightrope or high wire walker often uses a long stick for balancing in the same way as the forks are used in this experiment.

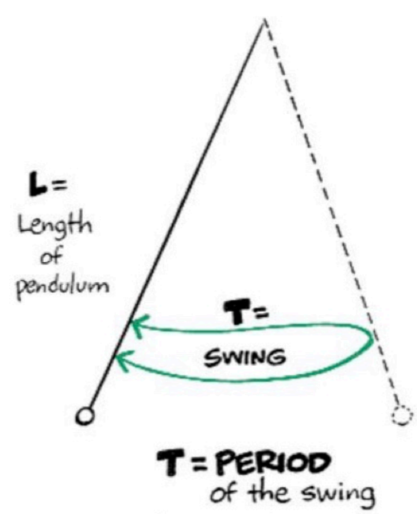
So How Much Is This Gravity Stuff and How Do I Calculate It?

Measuring Gravity with a Pendulum:

Materials:
stopwatch
pendulum = tie a mass to a string and hang it

$$T = 2\pi\sqrt{\frac{L}{g}}$$

Do:
1. Set the pendulum length at 0.5 m.
2. Time how long the pendulum takes to make 10 oscillations.
3. Using the formula given above, calculate the gravity.
4. Now set the pendulum length to .75 m and repeat the experiment. Once again, calculate the gravity.



Discuss:
How well do your measurements agree with the accepted value of ~9.81 m/s/s? How well do the two values compare? What may have caused the difference in the two values? (HINT: Think about the effect of pendulum length on the period.)

What Drives the Period of a Pendulum?

Objectives:

- To understand the change between Potential and Kinetic Energy
- Test the effect of variables on the period of a pendulum
- Utilize mathematics to analyze results of experiments

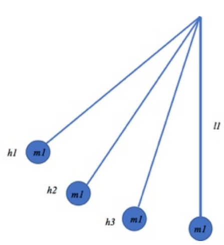
Materials:

ring stand w/ ring or other stand
meter stick
masses for pendulum bobs
paper, graph paper and pencils
string precut at different lengths.
stopwatch
tape

Procedure:

1. Using the materials, construct a pendulum that swings freely from the ring stand and count the number of swings in 15 seconds.
2. Record data and add data to class chart.
3. Analyze class data for variation.
4. Formulate hypothesis to explain variation.
5. Do not destroy original pendulum.
6. Select different variables to be tested.
7. Construct new pendulum to test variables.
8. Test variables by collecting data.
9. Record data.
10. Post Averages for variables for class discussion.
11. Draw inferences about what factor(s) affect the period of a pendulum.

Data Collection:
Example of data collection for variable of Height (*h*). Keeping the Length (l) and the Mass (m) constant. Run the experiment three times at each of three (3) different heights.



Trial Number	Length = *l*	Mass = *m*	Height = *h*	Swings in 15 sec.
1				
2				
3				
Average				

Trial Number	Length = l	Mass = m	Height = h	Swings in 15 sec.
1				
2				
3				
Average				

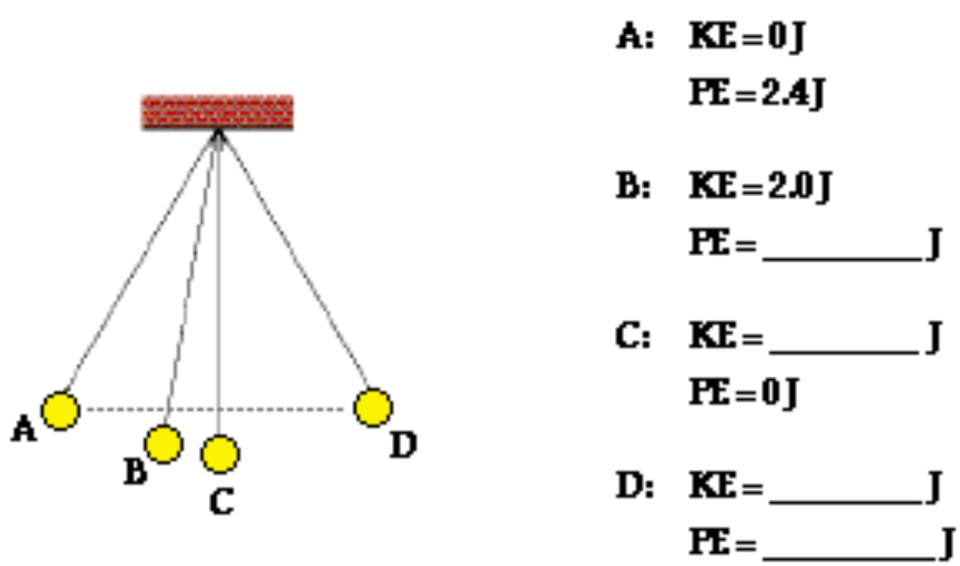
Trial Number	Length = l	Mass = m	Height = h	Swings in 15 sec.
1				
2				
3				
Average				

Content Discussion: will focused on: i) force and motion, ii) energy transfer, iii) science method and experimental design.

Assessment: Groups are to construct a pendulum that has a specific amount of swings per 15 seconds. (Amount should be some value that was not achieved during previous part of investigation.) Groups are to explain what method they used to determine pendulum setup for assessment task.

Challenge: Find examples of pendulums in real world situations.

Pendulums and Conservation of Energy:



Given that the fob has a mass of .2kg and that $g = 10\ m/s^2$ solve for h. ____________

Vector Addition

Procedure:

1. On a piece of graph paper, draw three line segments that meet near the center of the paper – do NOT make all your angles equal. Label the three lines A, B and C.

2. Place a piece of cardboard under the center of the paper. Insert a pushpin through the paper and into the cardboard at the point where the lines meet.

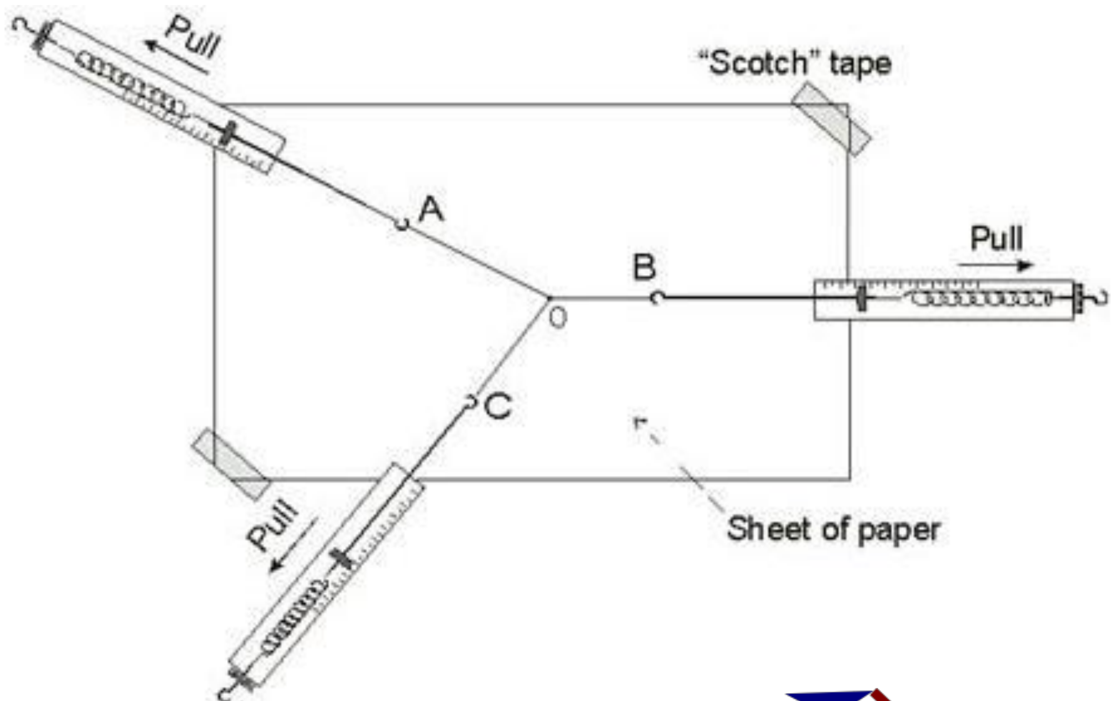
3. Hook three spring scales onto a large washer and slip the washer over the pushpin as shown here.

3. With the help of your partners, pull the spring scales along the lines that you have drawn. As you pull be sure that the washer remains stationary over the pushpin without touching it.

→ *Why is it important that the washer and the spring scales not touch the pushpin as you take your force readings?*

4. When the washer is steady over the pushpin, each partner should carefully read all three spring scales. Record these force readings next to the corresponding line on the paper.

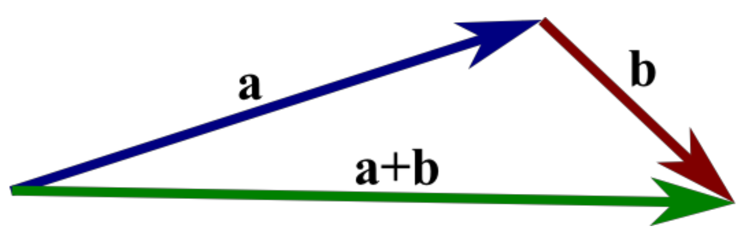
→ *Are the forces on the washer balanced? How do you know?*



5. Remove the pushpin and the cardboard from under your paper. Set a scale (2 cm = 1 N, for example) and draw appropriate length force vectors along the lines A, B and C to represent the 3 forces that you measured.

6. Draw vectors to represent **A** + **B**, **B** + **C** and **C** + **A**. To do this, use head-to-tail vector addition.

→ *How does each vector obtained from these additions compare to the original vector NOT used in each addition?*



→ *Suppose the combination of two forces acting on an object is the opposite of a third force acting on the object. What can be said about these three forces?*

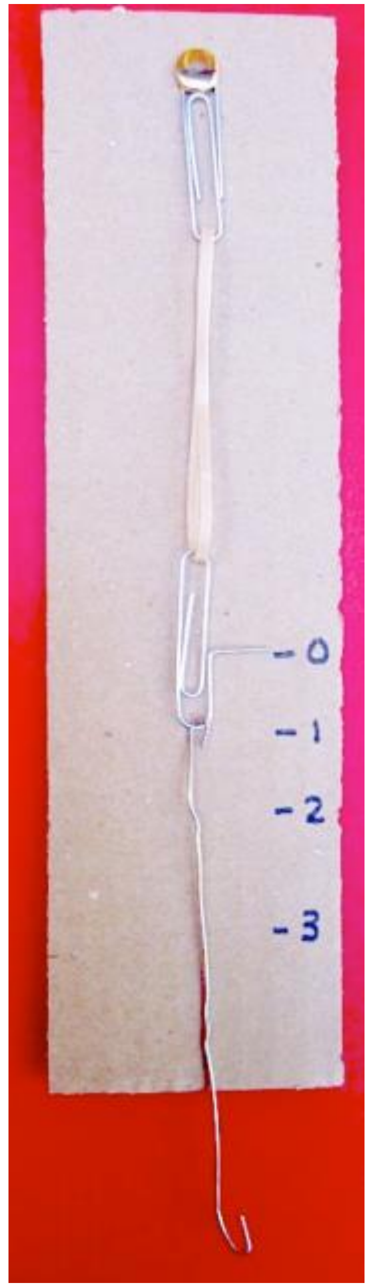
→ *What can you say about the motion of an object that is initially at rest when three balanced forces are applied to it?*

→ *What would you expect to happen to an object that is at rest when unbalanced forces are applied to it?*

Adapted from Force, Motion, and Energy, by Haber-Schaim, Cutting, Kirksey, Pratt and Stair; Science Curriculum, Inc, 2002

Make a Spring Scale

When you weigh something with a spring scale, you are really measuring the force of gravity on the object. In the metric system, force is measured in newtons. The abbreviation for newton is N.



Materials

- strip of cardboard, approximately 6 cm wide x 20 cm long
- rubber bands
- 3 or 4 jumbo paper clips
- brass fasteners
- drinking straw
- masking tape
- balance that will weigh to nearest whole gram
- brass cup hook
- calibration weights: 500 mL plastic water bottles can be filled with the appropriate amount of water

Make spring scale:

1. Poke brass fastener through one end of cardboard.
2. Attach one end of a paper clip to the brass fastener and the other end to a rubber band.
3. Tape a short section of the straw to the cardboard and put the rubber band through the straw. This will minimize friction with the cardboard.
4. Bend paper clips to make hooks on the bottom of the rubber band.

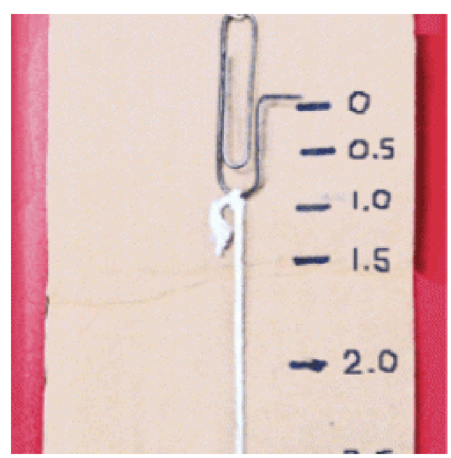
Make calibration weights:

A 100 gram mass weighs approximately 1 N here on earth.

1. Fill a water bottle until the combined mass of the bottle plus cap plus water is 100 g.
2. A brass cup hook screwed into the lid allows the bottle to be conveniently hung.
3. Similarly create a 200 g and a 300 g bottle to make calibration weights of 1, 2 & 3 N.

Calibrate the spring scale:

1. Use calibration weights to calibrate the scale from 0 to 3N. Be aware that the rubber band may not be "linear" in its stretch -- that is, the calibration marks may not be evenly spaced.
2. Label the calibration marks with their values.
3. If you want to recalibrate at some point, just cover the original marks with paper or masking tape and write the new values.



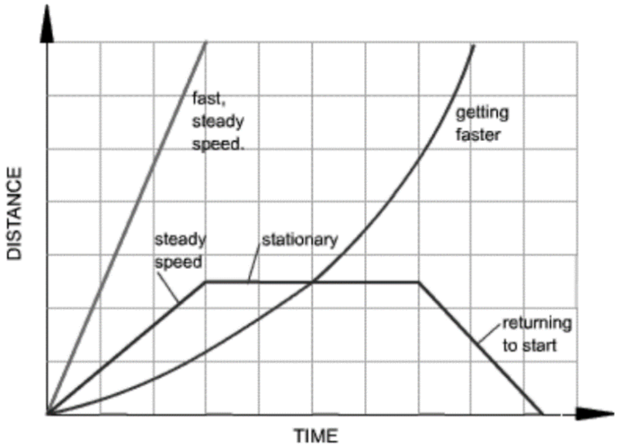
Rubber bands have a limited useful lifetime. Your calibration marks may change somewhat with repeated stretching, or if the rubber band is overstretched. You can use other rubber bands that are shorter, longer, lighter, heavier, etc. (e.g., if you want to measure larger weights, use a heavier rubber band -- or use two rubber bands side by side). The balance will have to be recalibrated if the rubber band is changed.

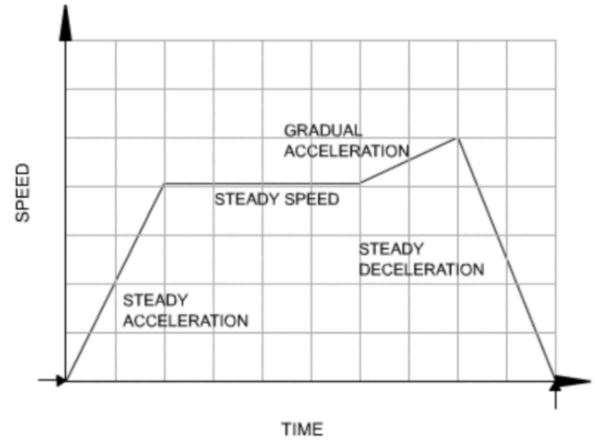
Motion Graphs

Describing the motion of an object is occasionally hard to do with words. Sometimes graphs help make motion easier to picture, and therefore understand.

Remember:

- **Motion** is change in position, using distance and time.
- **Speed** is the rate at which an object moves.
- **Velocity** is the speed and direction of a moving object.
- **Acceleration** is the rate speed or direction changes.





DISTANCE-TIME GRAPHS Plotting distance against time

- The steeper the graph, the faster the motion.
- A horizontal line means the object is not changing its position - it is not moving, it is at rest.
- A downward sloping line means the object is returning to the start.

SPEED-TIME GRAPHS also called Velocity-Time graphs.

A speed - time graph shows us how the speed of a moving object changes with time.

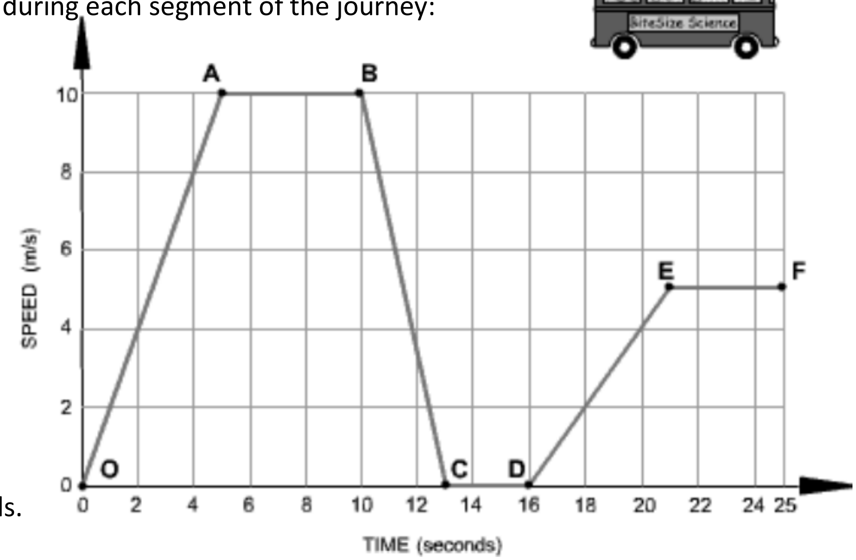
- The steeper the graph, the greater the acceleration.
- A horizontal line means the object is moving at a constant speed.
- A downward sloping line means the object is slowing down

Interpreting Motion Graphs

The graph shows how the speed of a bus changes during part of a journey:

Choose the correct words to describe the motion during each segment of the journey:

- accelerating
- decelerating
- constant speed
- at rest



Segment 0-A

The bus is ________________________________.

Its speed changes from 0 to 10 m/s in 5 seconds.

Segment A-B

The bus is moving at a _____________________ of 10 m/s for 5 seconds.

Segment B-C

The bus is ______________________________.

It is slowing down from 10 m/s to rest in 3 seconds.

Segment C-D

The bus is ____. It has stopped.

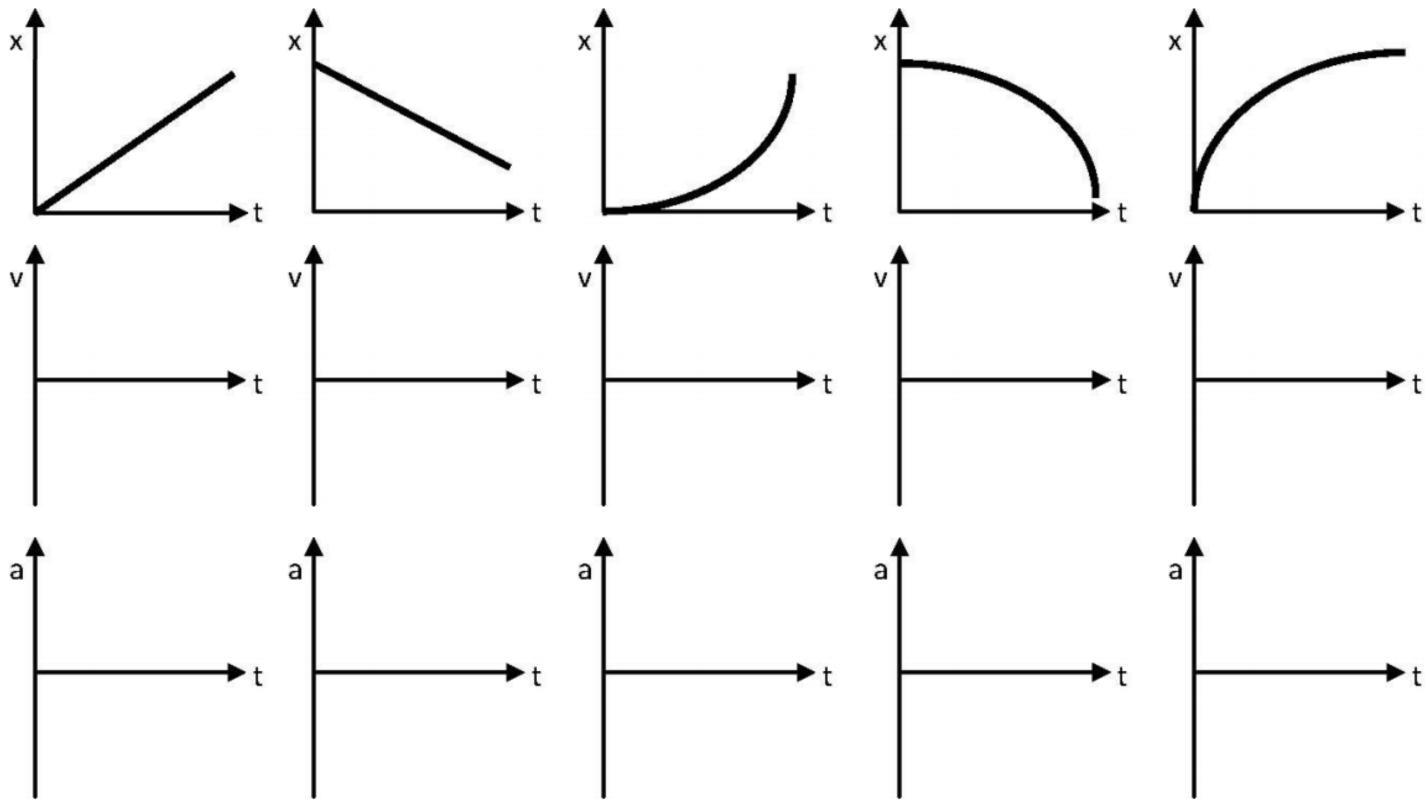
Segment D-E

The bus is ____. It is gradually increasing in speed.

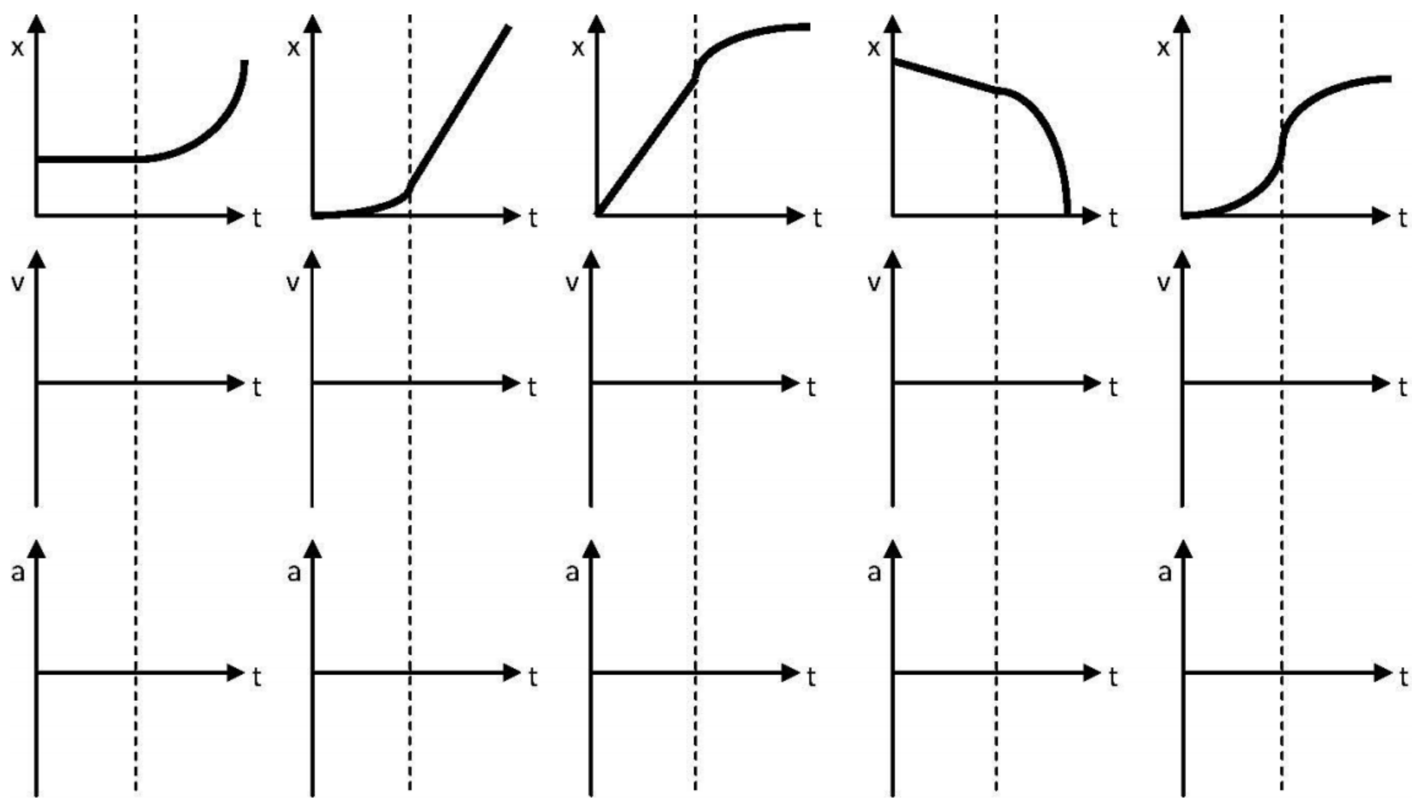
Motion: descriptions in graphs

Given the following position vs. time graphs, draw the velocity-time and acceleration-time graphs:

1 2 3 4 5



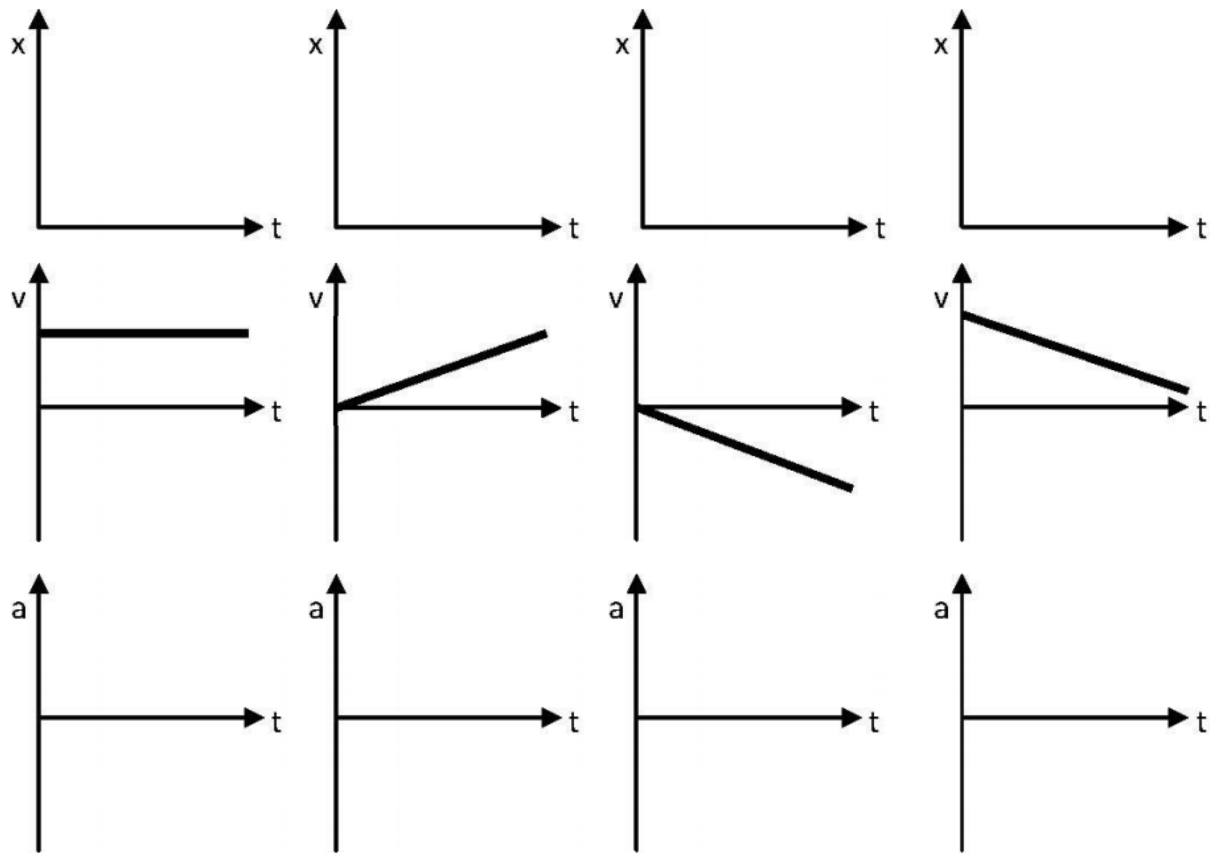
6 7 8 9 10



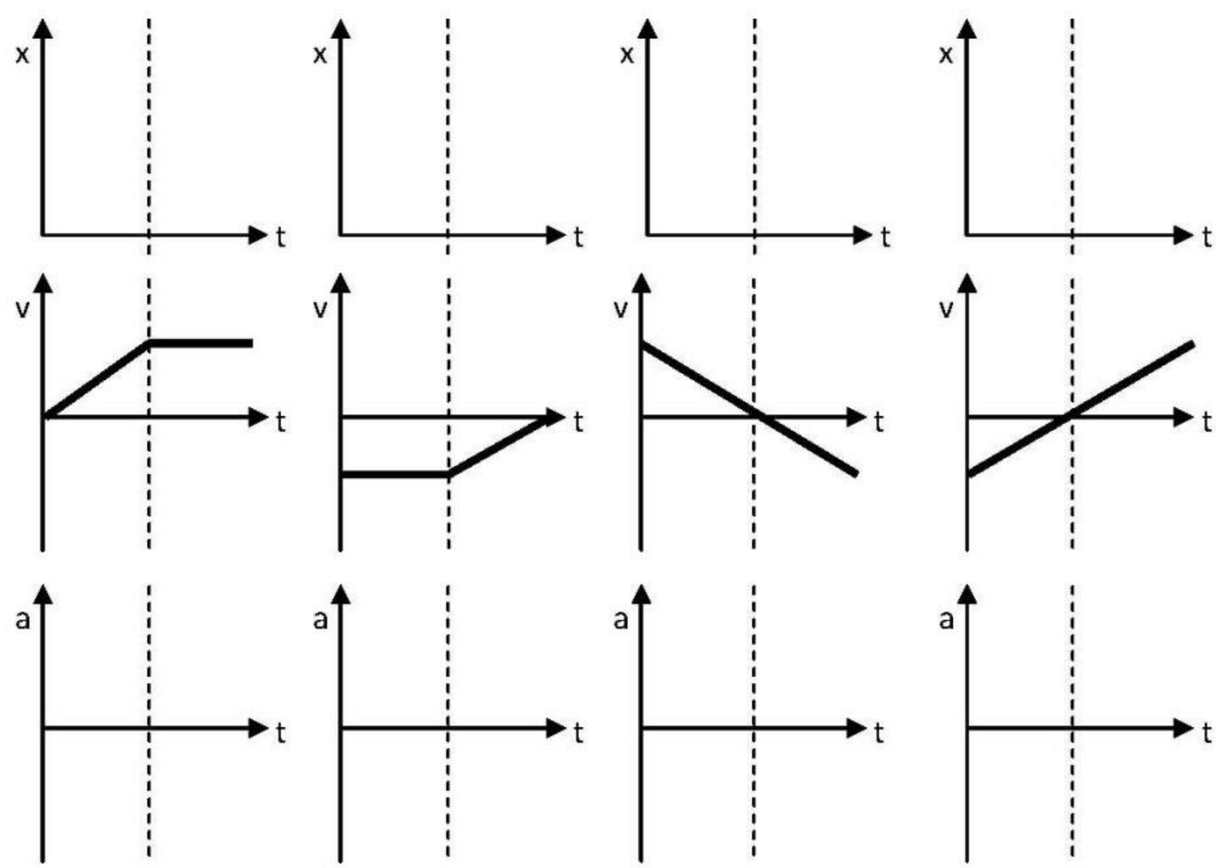
Motion: descriptions in graphs

Given the following velocity vs. time graphs, draw the position-time and acceleration-time graphs:

11 12 13 14



15 16 17 18

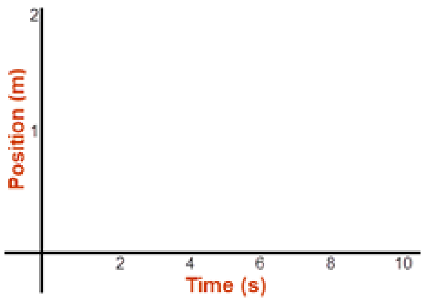


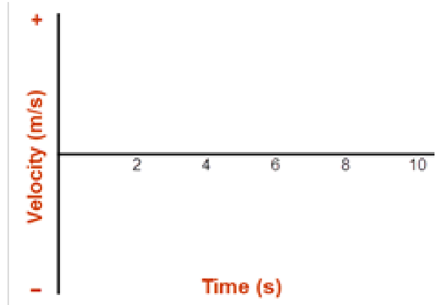
Motion: descriptions in words and graphs

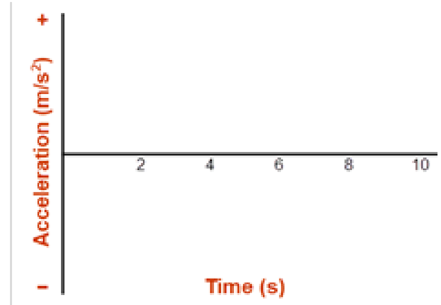
Draw 3 graphs to illustrate the motion of each situation:

a. position-time graph   b. velocity-time graph   c. acceleration-time graph

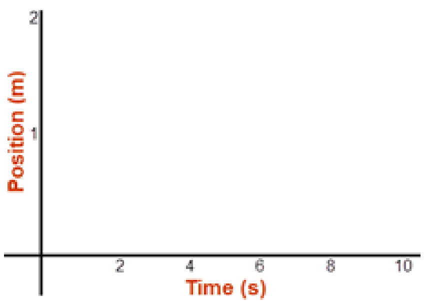
1. A ball is falling down at terminal velocity

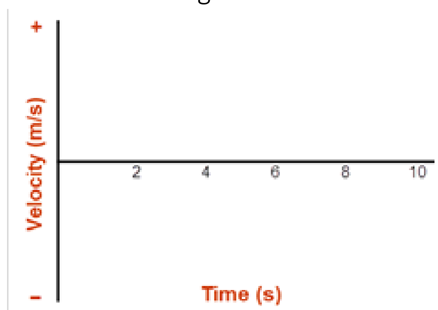


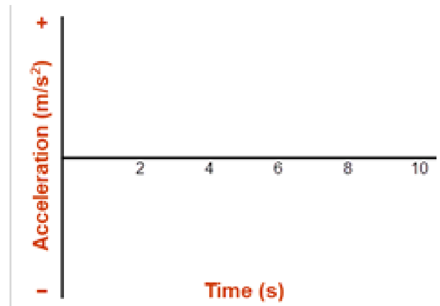




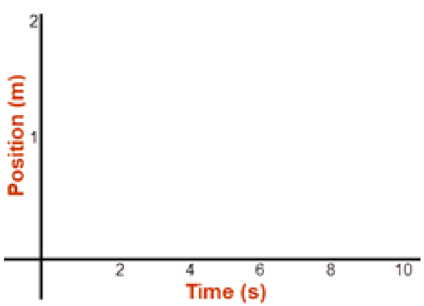
2. A ball is released from the top of a cliff and falls straight down.

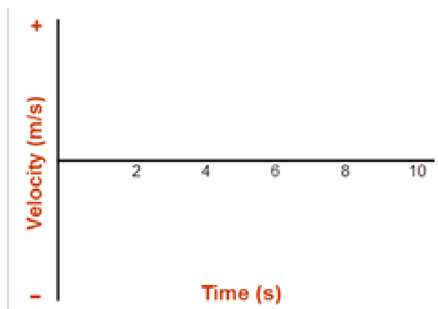


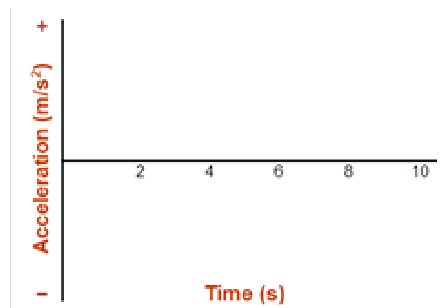




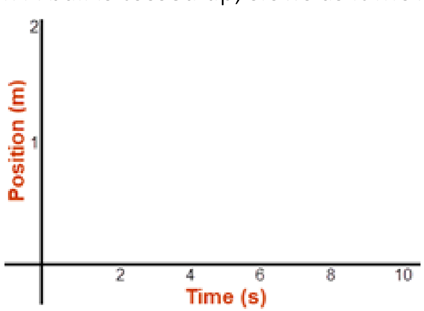
3. A ball is speeding up while rolling downhill.

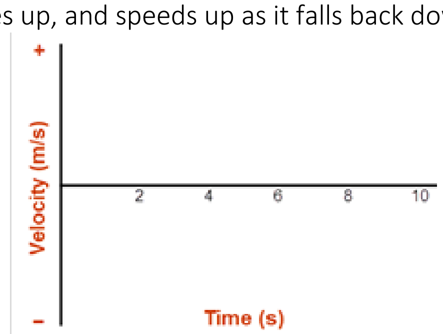


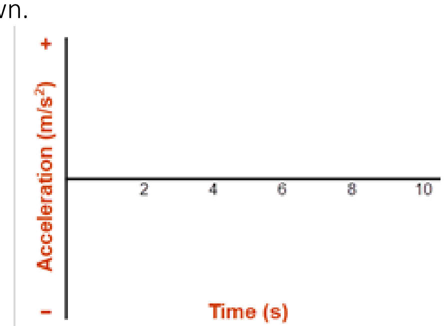




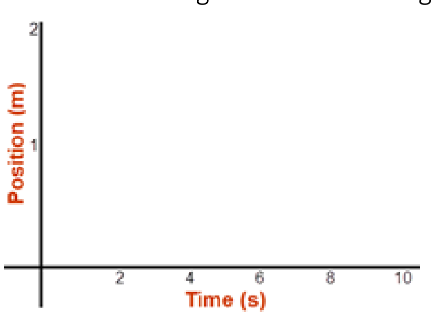
4. A ball is tossed up, slows as it moves up, and speeds up as it falls back down.

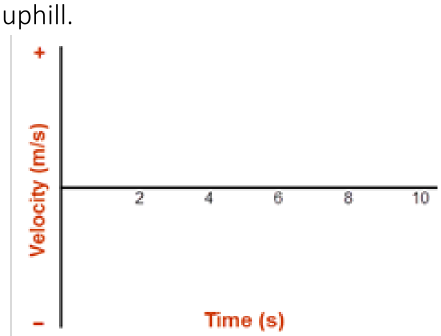


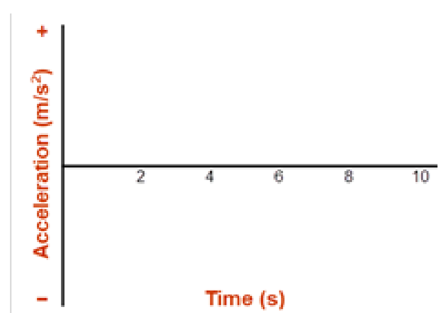




5. A ball is slowing down while rolling uphill.





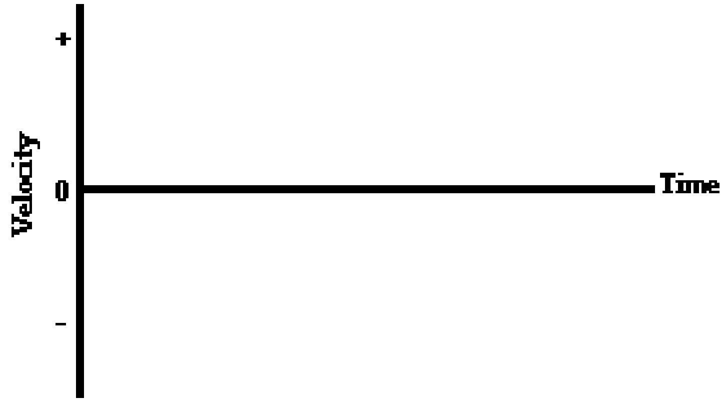


Motion: using graphs to calculate motion

Ball toss:

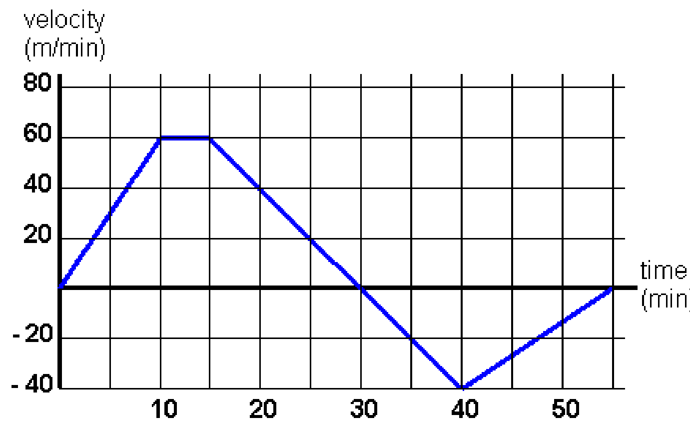
Draw a velocity-time graph for a ball that has been thrown straight up into the air and falls back down.

(neglect air friction)



Driving around town:

You are driving a car. The graph is a velocity vs. time plot of your motion.



a. How far did the car travel in the first 10 minutes?

b. What the average velocity of the car between 15min and 40min?

c. Explain what happens to the car's motion at 30min.

d. When is the acceleration of the car the greatest? When is the car not accelerating?

Police chase:

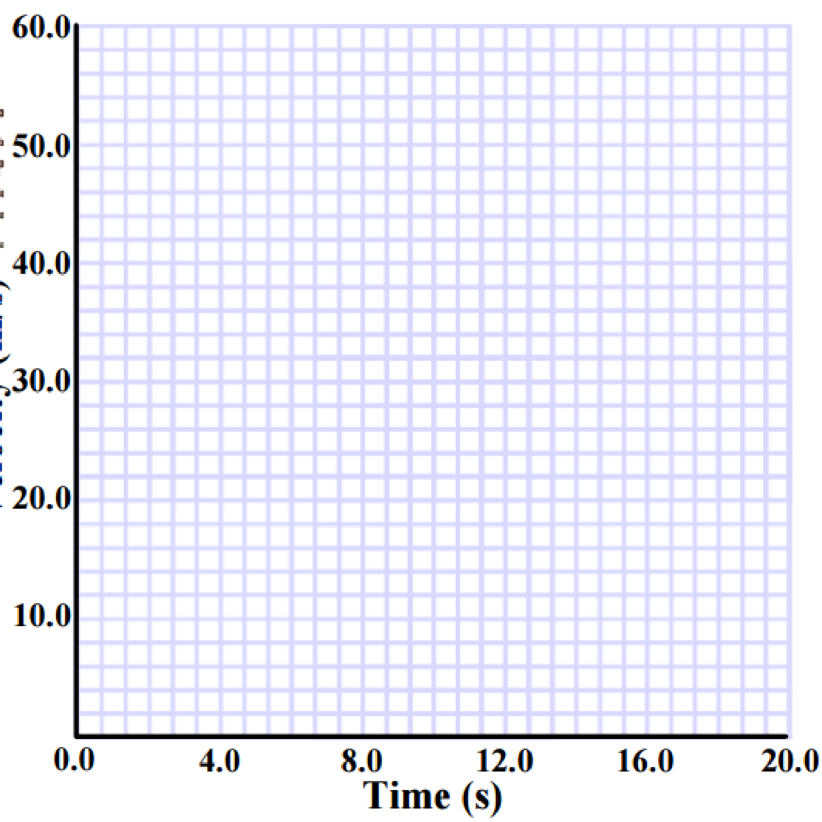
A police car is stopped at a red light.

As the light turns green, a truck zooms past traveling at a constant speed of 28 m/s.

The police car, sirens blaring and lights flashing, accelerates at 4 m/s^2

How many seconds will it take the police to catch the truck?

On the same graph, plot velocity-time graphs for the car and the truck.



Galileo's Kinematics Experiments

You will reproduce Galileo's results using an inclined plane. You will test 3 hypotheses relating to motion on an incline.

Galileo's reasoning suggested that objects rolling down a ramp behaved similarly to objects in freefall so that he could understand freefall by studying ramps. **He deduced that an object which is uniformly accelerated will travel a greater distance in each successive time interval such that the distance traveled is directly proportional to the square of the time.**
He also discovered that the speed of a falling object depends only on the height from which it falls.
One of Galileo's contributions to the experimental method was the idea of holding one or more variable constant while noting the effect when another variable is changed.

In this experiment there are FOUR VARIABLES.

1. The distance along the ramp which the balls rolls.
2. The steepness of the incline which is measured by the ratio of height to length of the ramp.
3. The height from which the ball is released on the ramp.
4. The time required for the ball to roll a certain distance down the ramp.

NOTES ON TIME MEASUREMENT

- Use a "starting gate" to avoid imparting to the can any uphill or downhill motion. The starting gate is a pencil or small ruler which holds the can in place, to be lifted when time starts. Think of how the boom at a parking lot operates. All of this is because we want to assure that the initial speed is zero, ie. stationary.
- To begin the timing, use a countdown of "5, 4, 3, 2, 1".
- To stop the timing, it is best to use a flat object such as a ruler or hard book as a physical stop. This allows you to use your sense of hearing along with sight to coordinate the stopwatch with the stopping point.

OBJECTIVES

1. Become familiar with the concept of hypothesis testing by experiment.
2. Observe and measure motion on an inclined plane.
3. Be familiar with Galileo's inclined plane.
4. Understand the relationships between distance, time, average speed, instantaneous speed, and acceleration.
5. Understand how to draw and interpret a "best fit" or regression line on a graph of experimental data.
6. Appreciate the difficulties in analyzing experimental data to make conclusions.

EQUIPMENT

Ramp, marble, meter stick, electronic timer

RAMP CONSTRUCTION

For the ramp you can use any flat, level object such as a board or a cardboard box. It should be about 1.25 meters long. If you don't have anything like that then you will have to improvise. Be creative. It doesn't matter what the ramp is made of as long as it is flat and strong enough to support your tin can without bending.
To raise one end of the ramp, use a pile of books. You may not be able to get the top of the ramp at exactly the height given in the instructions. Get it as close as you can and record the actual height in data tables A and B.

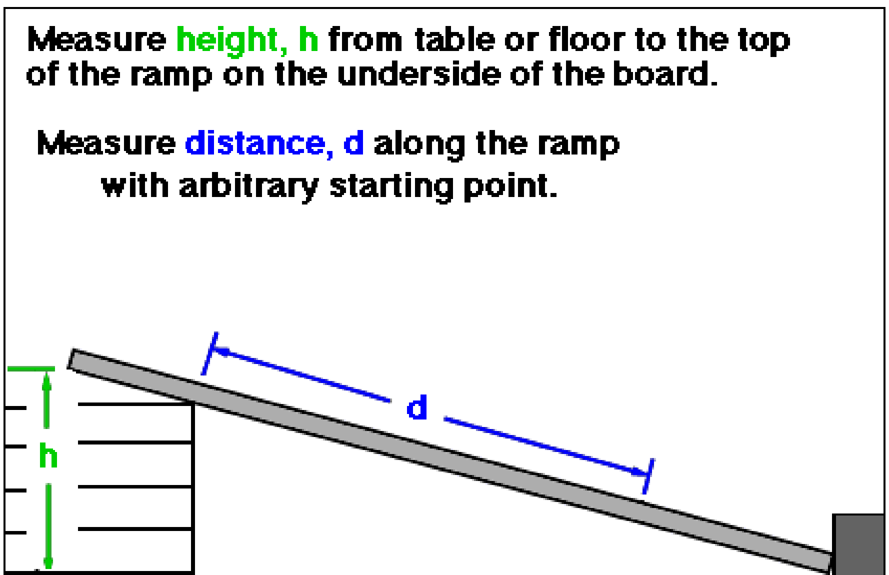


Figure 1

PROCEDURES and HYPOTHESES

HYPOTHESIS A: Distance is directly proportional to the square of time if acceleration is uniform.

In this part the distance d down the ramp is the variable while the angle of slope is constant.

1. Set up the ramp with h= 0.10 m above the table, (as shown in Figure 1.)
2. Starting with the cylinder at rest, use the stopwatch to measure the time to roll distance d = 1.0 meter down the ramp.
3. Take 6 time measurements, record in data table A. Cross out the highest and lowest times and determine the average of the remaining four times. (Sum four times and divide by four to find the average.)
4. Repeat steps 2 and 3 for distances of 0.80 m, 0.60, 0.40 m.

HYPOTHESIS B: Rate of acceleration is proportional to incline of ramp.

In this part the distance rolled down the ramp and the angle of slope are both variables.

1. The steepness of the incline can be measured by the ratio of height to length. Measure the total length of the ramp and record in data table B as L.
2. Copy the data from the first set of measurements in hypothesis A into the data table for hypothesis B, unless you prefer to collect that data a second time. (Time to roll 1.0 m when h = 0.1 m)
3. Raise the top of the ramp to 0.15 m.
4. Starting with the cylinder at rest, use the stopwatch to measure the time to roll 1.0 meter down the ramp.
5. Take 6 time measurements, record in data.
6. Repeat steps 4 and 5 for heights of 0.20 m, 0.25 m.

HYPOTHESIS C: Objects will reach the same speed from a given height regardless of incline.

In this part the starting height is held constant while the distance rolled down the ramp and the angle of slope are varied.

1. With the top of the ramp at h = 0.25 m as in part B, find the point P on the ramp that is y = 0.10 m above the table (see Fig 2).
2. Measure the length of the ramp from that point P to the BOTTOM of the ramp and record as d in data table (see Fig 2.)
3. Measure the time for the cylinder to roll from point P to the bottom of the ramp (start from rest as before).
4. Repeat steps 2 and 3 for ramp heights of h = 0.20 m, 0.15 m, and 0.10 m. NOTE THAT THE DISTANCE d, THE INCLINE OF THE RAMP, AND POINT P WILL BE DIFFERENT FOR EACH OF THE 4 TRIALS WHILE THE HEIGHT y REMAINS CONSTANT.

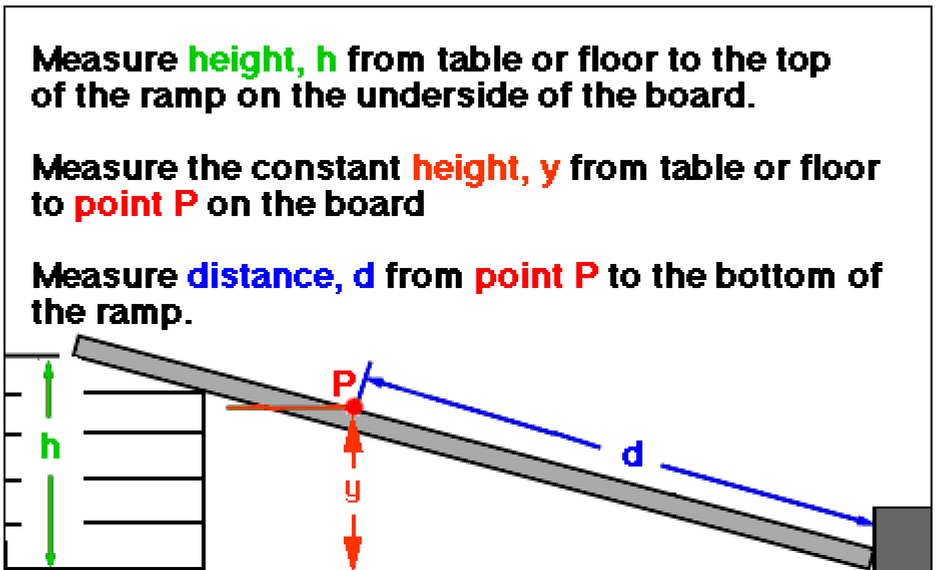


Figure 2

DATA TABLES

A. Acceleration vs. distance

Calculate the average time for six trials. Discard the highest and lowest in each trial so you will average the middle four values. Enter the average time in the data table. In each case use $t_{(avg)}$ for the times to calculate t squared. Draw a graph of distance versus average time squared for your data.

Table A

d (m)	t_1	t_2	t_3	t_4	t_5	t_6	$t_{(avg)}$	t^2
1.00								
0.80								
0.60								
0.40								

B. Acceleration vs. Slope

L is the total length of the board, to be recorded below. Distance rolled (d) is 1.0 meter. "t^2" means "t raised to the power of 2" or "t squared".
Height divided by length (h/L) is a measure of steepness of slope.
Distance divided by time squared (d/t^2) is proportional to acceleration.
The relationship will be linear if and only if acceleration is directly proportional to slope.

Table B

L = ______m	d = 1 m

h (m)	t_1	t_2	t_3	t_4	t_5	t_6	t_{avg}	t_{avg}^2	(d/t^2)	(h/L)
0.10	.	.	.	.	.	.	.	.	.	.
0.15	.	.	.	.	.	.	.	.	.	.
0.20	.	.	.	.	.	.	.	.	.	.
0.25	.	.	.	.	.	.	.	.	.	.

Table B1

h (m)	(d/t2)/(h/l)
0.10	.
0.15	.
0.20	.
0.25	.

From data table B, calculate the average time, the square of the average time, ratio d/t_{avg}^2 and the ratio h/L. For each of the four heights divide the two ratios from table B (divide d/t^2 by h/L) and enter the results in the table B1.

Examine the ratios and decide whether or not they are constant. Then plot a graph of (d/t^2) vs. (h/L) with h/L on the horizontal axis.

C. Speed vs. Height

"y" is the constant height from which the ball is rolled. "h" is the measurement to the top of the ramp as before, "d" is the distance from point P along the ramp to the bottom. See figure 2. Be sure you understand the meaning of the variables before you begin.

You want the ball to be rolled from the same height above the table each time. The point of release and the distance rolled down the ramp will be different for each trial.

Table C

y = 0.10 m

h (m)	d (m)	t_1	t_2	t_3	t_4	t_5	t_6	t_{avg}
0.10	.	.	.	.	.	.	.	.
0.15	.	.	.	.	.	.	.	.
0.20	.	.	.	.	.	.	.	.
0.25	.	.	.	.	.	.	.	.

Table C1

h (m)	(d/t)
0.10	.
0.15	.
0.20	.
0.25	.

For each height, calculate the average speed at the bottom of the ramp, d/t and enter the results in the data table C1. If the speed is the "same" then the ratios d/t should be equal.
Comparing the ratios of d/t decide whether or not you think the speeds are the same, then draw a graph of d vs. t for each of the four slope angles.

QUESTIONS FOR HYPOTHESIS A.

HYPOTHESIS A: Distance is directly proportional to the square of time if acceleration is uniform.
Using your data from part A, plot a graph of d (vertical axis) vs. t^2 (horizontal axis) . Draw a "best fit" straight line through the points.

A1. Is the graph linear?
A2. What does it mean if the graph is linear?
A3. What does a linear graph indicate about the acceleration of rolling objects?
A4. Does your data support hypothesis A? Briefly justify your answer.

QUESTIONS FOR HYPOTHESIS B

HYPOTHESIS B: Rate of acceleration is proportional to incline of ramp.

Using your data from part B calculate d/t^2 and h/L. Then plot a graph of d/t2 vs. h/L with h/L on the horizontal axis. Draw a "best fit" straight line through the points.

B1. Is the graph linear?

B2. What does it mean if the graph is linear?

B3. Does your data support hypothesis B? Briefly justify your answer

QUESTIONS FOR HYPOTHESIS C

HYPOTHESIS C: Objects will reach the same speed from a given height regardless of incline.

The average speed of an object under constant acceleration is distance divided by time. Plot a graph of d vs. t with t on the horizontal axis. Draw a best fit" straight line through the points.

C1. Is the graph linear?

C2. What does it mean if the graph is linear?

C3. Does your data support hypothesis C?

GENERAL QUESTIONS

G1. What are the variables in this experiment?

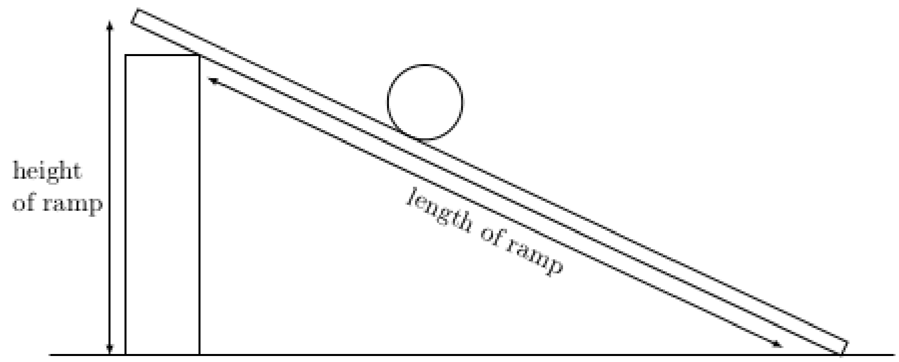
G2. How did you control the can to be sure it did not roll off the side of the board? Would this have any effect on the precision or accuracy of your measurements?

G3. How can you tell whether or not the points on the graph represent a linear relationship? Would you expect them to be perfectly linear? Why or why not?

G4. Briefly discuss the problems encountered in making kinematic conclusions from experimental data. Don't confuse the process of collecting data with the process of drawing conclusions from it.

Relating Speed & Potential Energy

- How will ramp height affect a marble's speed?
- How will ramp length affect a marble's speed?



1. Pick a variable (ramp height or ramp length) to vary. Hold the other variable constant.

2. Predict how that variable will affect marble speed. Do you expect to find a linear relationship, no relationship, an exponential relationship, an inverse relationship, etc.?

3. Build the setup. Position the ramp so that the top of the ramp is at a height of 5 cm. Roll the marble from a height of 5 cm & then measure how fast the ball is moving when it rolls across the table.

4. Vary EITHER the ramp height OR the ramp length and collect data for 4 different measurements.

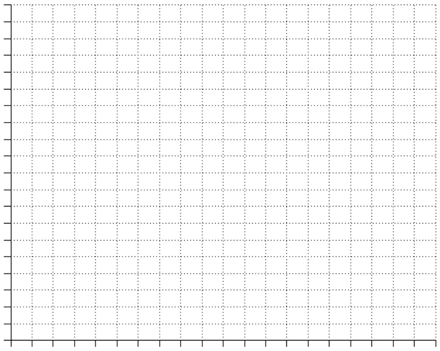
5. Repeat each trial 3 times.

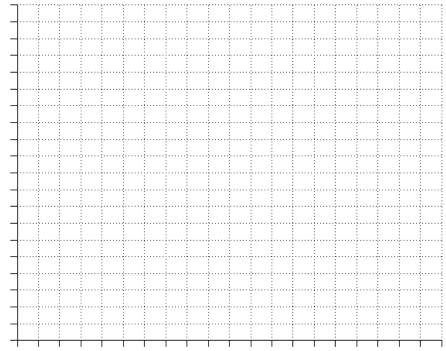
6. Graph: ramp height or length vs. marble speed.

Solving Motion Problems with Graphs

1. You are riding the bus home from a long trip. Your driver planned to drive the 106 kilometer trip at an average rate of 52 km/hour, but there's initially traffic on the highway and the bus can cover the first half of the distance at only 39 km/hr. Then traffic clears and your driver wants to get you to your destination on time, so he needs to speed up!

   a. Draw & label displacement/time and velocity/time plots of your trip, marking common times on x-axes of each.





   b. The speed limit is 70 km/hr. Will the driver break the law while driving the second half of the distance if your entire trip has an overall average 52 km/hr rate?

2. From the top of a tall cliff, you drop a rock. Half a second later, you drop a second rock (no air resistance).

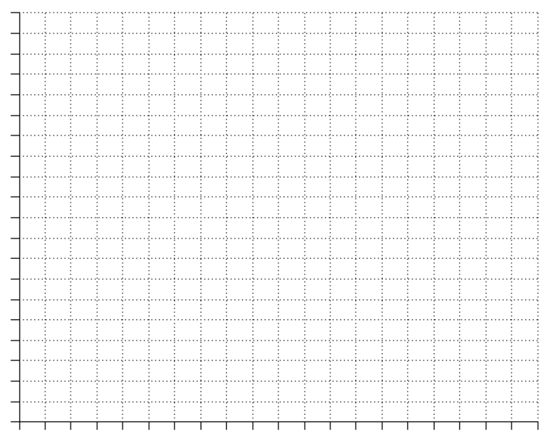
a.The separation between the rocks as they fall

- a. increases
- b. decreases
- c. remains constant

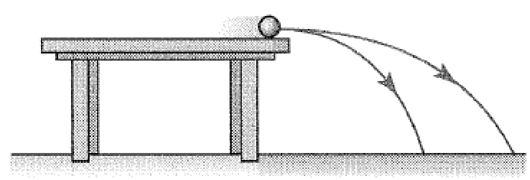
b. The second rock hits the ground

- a. less than half a second after the first
- b. a half second after the first
- c. more than half a second after the first

c. Sketch the motion of both rocks on the same graph:



3. You roll a ball off a horizontal tabletop twice, at fast & slow speeds. Compare/contast how long it takes to land in each case:

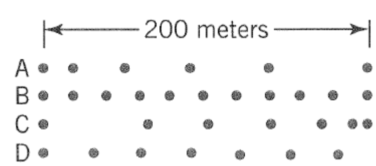


4. Your water bottle has a small leak. As you walk, 1 drop of water falls from your bottle every 3 seconds, leaving a trail of drops on the sidewalk. Here are patterns of drops you've left over the same 200 m stretch as you walk to the right. In which case(s) do you have:

a constant speed?

b. the greatest average speed?

c. the greatest instantaneous acceleration?



Projectile Motion

Objective:
To predict the landing spot of a projectile

Equipment: ramp, marble, meter stick, stopwatch, cup

Introduction:
An object in uniform motion has the equation for (horizontal) distance (x) travelled as: $x = v\,t$ (eqn. 1)
The velocity of an object is thus: $v = x/t$ (eqn. 2)

When you drop a rock on Earth, it falls to the ground and the distance it covers in each second increases. Gravity is constantly increasing the speed of the rock. If we let y represent vertical distance then the equation of the vertical distance fallen in t seconds is $y = \frac{1}{2} gt^2$ (eqn. 3) where g is acceleration due to gravity.

Starting from rest, the instantaneous falling speed v after time t is $v = gt$ (eqn. 4)

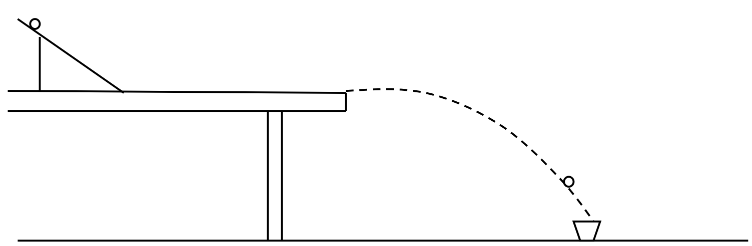
What happens when you toss a rock horizontally? The curved path that it takes is a combination of two straight line components of motion: one vertical and one horizontal. The vertical motion undergoes acceleration due to gravity, the horizontal motion does not. The secret to analyzing projectile motion is to keep the components separate.

Horizontal motion	
How far	$x = v\,t$
How fast	$v = x/t$
Vertical motion	
How far	$y = \frac{1}{2} gt^2$
How fast	$v = gt$

For the horizontal motion, use eqn. 1. For the vertical motion, use eqn. 3.

When engineers design bridges and architects design skyscrapers, they do not design and build by trial and error. It must be done correctly the first time! Your goal is predict where the marble will land when released from a certain height from a ramp. The final test of your computations and measurements will be to position the cup so the marble lands inside of it the first time!

Procedure:
1. Place a ramp on the table at least 1 m from the edge of the table. The marble must roll off the table horizontally. The vertical height of the ramp should be at least 40 cm.
2. Place a piece of tape on the ramp to mark the starting position of the marble. Place two more pieces of tape some distance apart on the horizontal part of the path that you will use to measure the time it takes the marble to travel across to calculate the velocity of the marble.



3. YOUR MARBLE IS NOT ALLOWED TO GO OFF THE END OF THE TABLE! Place a barrier to stop it (meter stick). Release the marble from its starting position on the ramp and record the time it takes to travel the distance you marked on the horizontal surface. Calculate the average time and determine the velocity of the marble for the horizontal speed.

Horizontal distance travelled by marble:_________

Trial	1	2	3	4	5
Time, t (s)					

Average time, t:________________ Horizontal speed, v_x =_______________

Projectile Motion (continued)

4. Measure the vertical distance, *y*, the marble will drop from the end of the table.

Y = ___________________

5. Using the appropriate equation, find the time *t* it takes the marble to fall from the end of the table to the floor (relate *y* and *t*).

Equation for vertical distance:

Solve this equation for vertical time of fall: **t = __________**

6. Now you need to predict the horizontal distance the marble travels, *x,* once it leaves the edge of the table. Write the equation and solve for your predicted distance.

Equation for horizontal distance:

Predicted distance: ***x***= __________

7. Measure and mark the location on the floor where you predict the marble will land. Be sure and account for the sides of the cup.
8. Notify the teacher and place the cup on your mark. Release your marble from the ramp and cross your fingers!

Summary:

1. Did the marble land in the cup on the first trial?______ Did the cup stay upright? What possible errors would cause the marble to miss or topple the cup over?

2. What is the relationship between the horizontal speed and the horizontal distance the marble travels once it leaves the table?

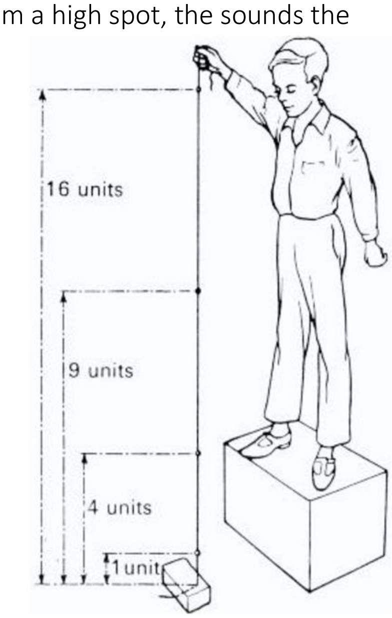
3. If you don't know it, is it possible to calculate the marble's initial horizontal speed? Suppose you know how far it will land on the floor.

4. Consider a bowler throwing a ball in a cricket game. If he is on a mound in the pitch that is4.8 m high when the ball leaves his hand, and the ball lands 18 down the pitch, the speed can be calculated. What is the speed, and why does the 4.8 m elevation make the calculation convenient?

String Drop Challenge

Objective: Tie metal objects to a piece of string so that when it is vertically dropped from a high spot, the sounds the metal makes in hitting the floor are evenly spaced "beats".

- To make the sounds occur at even intervals, should you tie the metal pieces at evenly spaced intervals along on the string? No!
- What sort of sound pattern will metal objects tied at evenly spaced intervals along the string produce?
- Consider acceleration due to gravity!



Graph:

- distance between objects vs. time (beat #) – what is the shape?
- distance between objects vs. time squared - what is the shape?

independent variable = the value you changed in the investigation & is written on the x-axis (horizontal axis).
dependent variable = variable you measured & is written on the y-axis (vertical axis).

Kinematics Equations

For arbitrary motion along a straight line, these equations apply:

displacement: $\Delta x = x - x_0$ time interval: $\Delta t = t - t_0 = t$

average velocity: $\bar{v} = \frac{\Delta x}{\Delta t} = \frac{x - x_0}{t}$

average acceleration: $\bar{a} = \frac{\Delta v}{\Delta t} = \frac{v - v_0}{t}$

For motion with constant acceleration, *a*, these equations also apply:

$x = x_0 + v_0 t + \frac{1}{2}at^2$ $v = v_0 + at$

$v^2 = v_0^2 + 2a(x - x_0)$ $\Delta x = \bar{v}t = \frac{(v + v_0)}{2}t$

1. A whale swims due east for a distance of 6,9 km, turns around and goes due west for 1,8 km, and finally turns around again and heads 3,7 km due east.
(a) What is the whale's total distance traveled? (b) What are the magnitude & direction of the displacement of the whale?

2. As the earth rotates through one revolution, a person standing on the equator traces out a circular path whose radius is equal to the radius of the earth (6,8 × 10^6 m). Calculate the average velocity of this person in meters per second.

3. A motorcycle has a constant acceleration of 2.5 m/s^2. Both the velocity and acceleration of the motorcycle point in the same direction. Calculate how much time is required for the motorcycle to change its velocity from
a. 21 to 31 m/s b. 51 to 61 m/s

4. Describe an example from your own experience of a situation in which an object had a zero velocity for just an instant of time, but had a nonzero acceleration.

5. A horse runs half the remaining distance to the barn every 10 seconds. The horse follows a straight path and does not change direction. Does the horse's acceleration have a constant magnitude? Write a few sentences to describe why or why not.

6. The barrel velocity is the velocity at which a bullet is moving when it leaves the gun's barrel. A short handgun has a greater barrel velocity than a long rifle. In which weapon is the acceleration of the bullet greater? Explain why.

7. You go for a stroll and your average walking velocity is a positive value. Is it possible for the instantaneous velocity at any point during your stroll to be negative? Explain why or why not.

8. You and a friend are driving next to each other on a multi-lane road. If your car has a greater velocity than your friend, must you also necessarily have a greater acceleration? Explain why or why not.

9. Sipho can run a 10,0 km race with an average pace of 4,39 meters/second. Thoko can run the same course with an average pace of 4,27 m/s. If Sipho wants to give Thoko a head start so that they both cross the finish at the same time, how many seconds later should he start?

10. You're stuck on the runway, waiting for your delayed plane to leave. Looking out a very narrow window, you see another plane arrive on a parallel runway, moving at 45 m/s. If the other plan is 36 meters in length, for how many seconds is this plane visible to you?

---

1. a. 12,4 km b. 8,8 km east.

2. 464 m/s

3. a. 4 s b. 4 s

4. many possible answers – a ball thrown straight up in the air.

5. no –In each 10 second time interval, the displacement is smaller by a factor of 2. Thus, the ratio (delta x)/t becomes smaller by a factor of 2.

6. Handgun has greater acceleration. Explain why!

7. Yes. Explain why!

8. Not necessarily. Explain why!

9. 64 seconds

10. 0,80 seconds

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